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Plastic Entwined: Petromaterials in the Energy Transition

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by

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ABSTRACT

Plastic Entwined: Petromaterials in the Energy Transition

by

Rex Miller Simmons

Many conflate the end of fossil fuels with the end of oil. Instead, oil companies are playing a central role in the development of renewable energy technologies in the energy transition. This thesis attempts to understand how the petrochemical industry has become central as the proprietor of materials in technological design, through a case study of Formosa Plastics Group and the petrochemical industry in Taiwan. Petrochemical companies serve as purveyors of plastic products that have become essential tools that society relies on, but the continued relationship between society and petromateriality affixes a specific configuration of centralized oil production and consumption. Through review of Formosa Plastic's ventures into renewable energy technology, my findings show how the history of oil based industrialization has led to an industry that focuses on oil's material properties. Petromaterials have become entwined into the basis of commodity production, but the problems posed by plastic and the centralization of petrochemical production, as well as a lack of a large-scale material substitute, pose existential difficulties for decentralized or degrowth visions of societal organization. This is especially clear in the relationship between petrochemical companies and renewable energy technology, as even the solutions to the environmental crisis of global climate change are seemingly forcibly constrained to the materiality of oil.

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I. Introduction

Oil companies are playing a central role in the development of the energy transition. This fact was brought to light at the 2023 United Nations Conference of the Parties (COP 28) summit in Dubai, when a small tweak in the language of a draft climate agreement during the final days of the summit provoked an outcry from activists and policy makers alike. The agreement was altered to remove language about the "phase out" of fossil fuels, replaced instead with language that encouraged "transitioning away from fossil fuels in energy systems, in a just, orderly and equitable manner … so as to achieve net zero by 2050."[1] Environmental advocacy organizations criticized the agreement as insufficient for addressing the immediacy of climate change, as it emphasized an "all of the above" approach to climate mitigation, which "promotes renewables as a complement to fossil fuels rather than a replacement for them" and encourages exploration of carbon capture and low-carbon emission technologies.[2] This shift in language sparked conversations about the role of oil companies in the energy transition, whereby a "transition away" from fossil fuels came to represent oil company's superficial investments in renewable energy and reliance on experimental technologies, as opposed to the project of fossil fuel "phase out." Yet, why exactly oil companies are interested in renewable energy may be more than just a project of public deception.

The agreement was championed by COP 28 President Sultan Al Jaber, CEO of the United Arab Emirates' national oil and gas company Abu Dhabi National Oil Company (Adnoc), whom many accused of using his position to lobby for interests of global oil and gas companies. Al Jaber

[1] UNFCCC, "Conference of the Parties serving as the meeting of the Parties to the Paris Agreement Fifth session United Arab Emirates," December 13, 2023.

[2] Reisch, Nikki "What will it Take to Phase Out Fossil Fuels?" *Project Syndicate*, December 6, 2023.

also heads the state-owned renewable company Masdar, and used COP 28 as an opportunity to explore global commercial interests of both Adnoc and Masdar. It was revealed in late November that Al Jaber had intentions to "raise commercial interests with almost 30 countries" after an internal document was leaked to the Center for Climate Reporting by a whistle-blower. These meetings included talks with Brazil's environmental minister Marina Silva on rescinding the UAE's status as 'tax-haven' to permit petrochemical and renewable projects in Brazil, and a meeting with China's vice minister for the environment Zhao Yingmin on possibilities for future LNG (Liquified Natural Gas) projects.[3]

After COP 28, organizations including 350.org expressed similar dissatisfactions with the role French energy company Total Energies was portraying in the energy transition. Advocates claim that Total is overstating their investments in renewable energy presenting a smattering of experimental technological developments and as a greenwashing technique for their fossil fuel expansion.[4] The report criticizes Total Energies for continuing to expand their fossil infrastructure in natural gas and using investments in a project led by Gautam Adani, an Indian coal tycoon, to distract from their new fossil investments. Total called their 2.5 billion USD investment in Adani solar developments "the largest investment ever made in renewables" The project has been characterized by conflicts over land between farmers and the Adani energy conglomerate.[5] What

[3] Stockton, Ben "COP 28 President secretly used climate summit role to push oil trade with foreign government officials" *Center for Climate Reporting*, November 27, 2023.; Tabuchi, Hiroko "Files Suggest Climate Summit's Leader is Using Event to Promote Fossil Fuels" *New York Times*, November 28, 2023.

[4] Guibert, Sophie "This is what a Total Phase Out Looks Like" *350.org*, December 7, 2023

[5] Binctin, Barnabe and Guillaume Venentiay, "Gautam Adani: coal tycoon and fake green friend of Total in India" Observatoire des Multinationalles, July 13, 2023. https://multinationales.org/fr/enquetes/multinationales-vertes/

this report inadvertently shows is that these sizable investments in renewables are occurring alongside new investments in fossil fuel reserves and infrastructure.

It's understandable why policy makers and activists are suspicious and frustrated with the central role of oil and gas companies in the so-called energy transition, especially when considering the long history of these companies denying responsibility for and obstructing action on climate change. The current COP 28 agreement's net zero scenario would likely exceed the carbon emissions necessary to stay within the Paris Agreements targets for warming and relies on undeveloped carbon capture technology to sequester carbon dioxide from continued greenhouse gas (GHG) emissions. For achieving essential reduction in carbon emissions, the difference between 'transition away' and 'phase out' is crucial for mitigating the severity of climate change from fossil fuel combustion. Seeing these companies producing renewable energy and presenting these technologies alongside convenient solutions of carbon capture, and promoting gas as an intermediary fuel seem disingenuous and as a strategy for public deception. Ultimately, environmentalists' frustration is that control over renewable technologies is dominated by fossil industries in a way that seems reminiscent of the same obstructionism characterized by the climate denialism strategy of the last few decades.

Aside from deception, why else might an oil conglomerate have any interest in producing renewable energy technologies? This project began as I was trying to make sense of the seemingly contradictory business strategies pursued concurrently by Formosa Plastics Group (FPG), the largest petrochemical company in Taiwan and one of the largest petrochemical conglomerates in the world, with subsidiaries across the United States, China, and Vietnam. On the one hand, Formosa Plastics is pursuing one of the largest plastic plants to be built in the United States in a region of Louisiana known as Cancer Alley, a notorious petrochemical corridor that has some of the worst emitters of air pollutants in the country. This massive ethylene plastics plant, known as the Sunshine Project, is a 9.4 billion dollar petrochemical installation slated to be built in St James Parish, a historically Black region in Louisiana. The same towns along the Mississippi river where the ancestors of many current residents were enslaved into agricultural labor are now the site of the majority of petrochemical production in the United States, and Formosa has been eyeing the site for their massive ethylene cracker plant, despite significant protest from local organizing group Rise Saint James.[6] While the Sunshine Project has received significant scrutiny, including the EPA temporarily suspending air permits that allowed for emissions greater than the legal limit of sulfur dioxide, at the time of writing the plans for development are moving forward uninhibited after brief EPA review.[7]

On the other hand, FPG has been making headlines in Taiwan for their new ventures into renewable energies technology, specifically their plan to build a large battery manufacturing plant at the Changbin industrial zone in central coast Taiwan. The new subsidiary, called Formosa Smart Energy Tech, aims to expand FPG's pre-existing involvement in lithium battery production to create large scale energy storage systems. FPG invested over 500 million USD into a new battery

[6] Forensic Architecture. "Environmental Racism in Death Alley, Louisiana: Phase 1 investigative Report." *Forensic Architecture*, 2021.

[7] Trimber, Alex. "Louisiana Court Ruling Reverses Lower Court Decision and Upholds Air Permits for Formosa Plastics' Massive Petrochemical Complex in Cancer Alley" *Earth Justice*, Jan 19, 2024.

manufacturing plant as part of a government-led initiative to develop a renewable energy export terminal, producing what would become the largest battery factory in Taiwan. In addition to battery storage, they hope to expand into electric vehicle production, fulfilling a long term business goal of Formosa's founder Y.C. Wang.[8] [9]As I looked deeper into their production in Taiwan, a story that was distinctly different from their US investments emerged: a company founded through postwar US aid to establish a plastics export industry had created a vertically integrated supply chain that produced everything from plastic raw materials to integrated circuits. This company's success was not just producing fuel to burn, but turning oil into as many different things as possible as goods to be bought and sold.

This project was initially guided by a seemingly simple question: How are business-as-usual operations for the petrochemical industry affected by the energy transition? The aim is to try to understand how the incentives to decarbonize to abate climate change are altering the structures and functions of companies, with FPG as a reference case to understand the relationship between the oil industry and the next regime of energy technology. However, as I delved into the history of the company, it became clear that the typical industry behaviors for a petrochemical materials company were strikingly different from the 'business-as-usual' behavior of oil companies with unrestrained access to a supply of fossil fuels. The geopolitical constraints on Taiwan's access to

[8] Hu, Huasheng. "Wang Ruiyu takes over from Wang Yongqing and builds Formosa Plastics into a sacred mountain of new energy to protect the country?" *Vision Magazine*, July 6, 2022; Guo, Yi. "Formosa Plastic Wang Yongqing's unfinished dream? The largest lithium-iron battery core factory in Taiwan is located in Changbin" *Vision Magazine*, April 13, 2023.

[9] Y. C. Wang is the name used in the economics literature for FPG founder Wang Yongqing (王永慶, also Wang Yung-Ching).

upstream fossil sources incentivized Formosa Plastics to pursue applications of petrochemical products in as many downstream applications as possible, using their plastic products in home appliances, synthetic rubber for industrial applications and synthetic fibers for textiles, and even including ventures into semiconductor, integrated circuit, and lithium battery production. At the same time, these conditions offer new insight into how petrochemicals, and oil companies in general, serve as intermediary suppliers of material for many of the 'true' large renewable solutions, but rely on large scale production of plastics and toxic petrochemicals to sustain the relatively smaller portion of specific materials that serve as inputs for technological production.[10] In the case of highly diversified companies like Formosa Plastics, this even takes the form of production of the technologies themselves, including integrated circuits, solar arrays, wind turbine components, lightweight building materials, and battery technologies, while the company continues to expand its production of traditional plastics.

Instead of assuming that fossil companies' involvement in renewable energy is purely greenwashing, what if we consider the specific ways within the fossil industry that petrochemical production and capital is enabled by new demands for the production of new energy technologies? While the interests of fossil fuel producers are affected by restrictions on carbon, the petrochemical industry is able to recoup losses from fuel production through adding value to material downstream. This is partly because the inputs of petrochemical production come from the byproducts of oil refining, which are turned into chemicals and plastics that make up the material

[10] 'True' renewable solutions refers to the production of renewable energy technologies such as wind and solar, as opposed to 'false' renewable solutions that might rely on experimental technologies, such as carbon capture, to negate continued carbon emissions.

basis of many modern goods. As new petrochemical companies explore strategies to make material feedstocks straight from crude oil, a process known as oil-to-chemical, it is clear that the future of oil as material will not end with a 'phase out' of fossil fuels. While the fossil fuel market is opposed in one way or another to the large-scale development of renewables in the energy transition, the market for fossil materials is expanded by demands for specific technologies, and thus specific materials.

What is alarming is not just that renewable energy is being used as a greenwashing strategy for large fossil fuel companies, but also that there is a certain compatibility between fossil companies and the production of renewable energy technology. Solar, wind, and carbon capture technologies will be necessary to exist alongside new and existing oil and gas infrastructure for their long term feasibility, while providing many of the materials necessary to produce energy and other technologies necessary for negotiating the effects of modern fossil production on a greater environment. The compatibility of this cyclical mitigation risks entrenching energy technology production within an existing regime of fossil production that utilizes scalar efficiency of high volume fuel consumption to yield cheaper materials and production techniques. These early shifts could determine the course of renewable energy technology as one parallel or within the continued materialities of oil and gas.

This reliance on fossil modes of production for renewable energy technologies and simultaneous attempts to regulate their GHG emissions has created conundrums for environmentalists and industry alike. On one side, climate activists are combating hegemonic oil production and demanding phase outs of fossil fuel use, yet to enable the technological production necessary for the energy transition, simultaneously rely on fossil modes of production to create such technology. On the other side, industry actors are baffled by the demands of this simultaneous reliance and dissension: 'decarbonize' or 'defossilize' plastic production when plastic is made of fossil carbon,[11] create technology to capture carbon and produce circularity of plastic that has become embedded in every ecological system, and provide the same access to energy and material but without access to a source feedstock. These contradictions within the production of modern materiality as well as the binds of activism against it are perhaps leading to the bullish behavior of the fossil fuel industry during the early transition period, as they know they are the proprietors of many renewable technologies. As Alice Mah (2023) has discussed in her recent book, the petrochemical industry can often skirt responsibility for its contribution to global toxicity by showcasing its "monopoly on the technical expertise needed for providing many green technological 'solutions.'"[12] Within this dependency, fossil companies are making sizable investments in decarbonization technology as is convenient to sustain their existing capital.

The importance of oil in providing the materiality for continued economic growth, including this new energy system, is evident in projections of oil extraction into the future. According to the International Energy Agency stated policy scenario, total energy demands from fossil fuels are expected to decrease, but the use of oil globally will likely stay at similar levels to today.[13] Similarly,

[11] Terms used and discussed as part of the Fair Plastics forum held by Virginia Tech. Field Notes March 15 2024

[12] Mah, Alice. *Petrochemical Planet: Multiscalar Battles of Industrial Transformation*. Duke University Press, 2023. 121

[13] IEA (International Energy Agency), Fossil fuel demand in the Stated Policies Scenario, 1900-2050, IEA, Paris, 2022

while oil use is expected to fall in "advanced" economies, oil use will increase in emerging markets and only fall slightly in China.[14] This is all in the greater context of plastic and material production projected to continue to rise in the coming decades.[15] As an added difficulty for understanding the end uses of oil, the standard measure of 'energy' consumption often only looks at the quantity of oil that is consumed as input, representing a large unknown about how much oil is actually used as fuel and how much is used as material. Even the way that oil is conceptualized assumes that it is only a fuel source and ignores the ways that petromaterials are linked to regimes of oil beyond its energetic sources.

In part, this compatibility between petromaterials and alternative energy regimes is unrecognized because the objects made from fossil material are abstracted from both the historical, material, and industrial process that formed and created it. The design malleability of plastic, combined with the developmental industrialization of petrochemical production and later outsourcing of technology production to the global South, allow for energy technology to exist in a vacuous space where it is seemingly made of nothing, only that it is producing less carbon than what would have been made otherwise through fossil fuel use. Electric vehicles, solar panels, wind turbines, are substituted in for fossil fuel technology in a dichotomous process that ignores the messy interdependencies created through petrochemical industrialization and modern industrial production, and thus demands for these technologies to become ever cheaper, ever more accessible for decarbonizing nations enables existing modes of fossil production. From the bronze age to the

[14] IEA, Oil demand by region in the Stated Policies Scenario, 2000-2050, IEA, Paris, 2023

[15] IEA, "The Future of Petrochemicals: Towards more sustainable plastics and fertilisers," OECD/IEA, (2018), 18.

iron age, the materiality of technology has defined the capabilities of production and constrained or enabled social formations around it. Plastic, and the essential role fossil companies play in its production and the technology made from it, is no different.

In the support of an environmentalism that is conscious of the history of oil based industrialization and its ongoing impact on fenceline communities, writing off the interests of oil companies in developing renewable energy technologies that are necessary for the energy transition as solely obstruction or regulatory capture ignores an important aspect of how technology has been historically and materially produced as an interlinked part of fossil fuel production. This thesis attempts to understand how the petrochemical industry has become central as the proprietor of materials in technological design, through the history of production of petromaterials in Taiwan and the socioenvironmental consequences of its continued widespread use and production. To interrogate the position of this industry in the energy transition, I ask what are the historical and contemporary roles of petromaterials, and how their continued use affect possible sociotechnical orders. By sociotechnical orders, I mean the ways that society and technology have co-evolutionarily constructed each other, and produced systemic configurations that constrain and enable possibilities of relationships between society and technologies.[16] This thesis examines how the current sociotechnical order of oil and petrochemical industrialization, infrastructure, and material, shape the possibilities of how technology can be imagined, designed, and produced. Petrochemical companies serve as purveyors of plastic products and other petromaterials that

[16] Callon, Michel. "The sociology of an actor-network: The case of the electric vehicle." In *Mapping the dynamics of science and technology: Sociology of science in the real world*, pp. 19-34. London: Palgrave Macmillan UK, 1986.

become essential tools that society relies on, but the continued relationship between society and petromateriality affixes a specific configuration of centralized oil production and consumption. My findings show that through the history of oil based industrialization, petromaterials have become entwined into the basis of commodity production in a way that resembles fuel uses, but the problems posed by plastic's materiality and the centralization of petrochemical production, as well as a lack of a large-scale material substitute, pose existential difficulties for decentralized or degrowth visions of societal organization. This is especially clear in the relationship between petrochemical companies and renewable energy technology, as even the solutions to the environmental crisis of global climate change are seemingly forcibly constrained to the materiality of oil.

The first chapter looks at the founding of Formosa Plastics and the oil industry in Taiwan from its post war origins to highlight the role of US aid in expanding a system of petrochemical production that provided many materials that have come to represent the material "good life," as a strategy of refuting communism in Europe and East Asia while benefiting its own oil industry. Not only did US aid found Formosa Plastics directly, this process of coordinated industrialization between the US and KMT established a plastic and synthetic textile export industry in Taiwan that set a path for future development, a process that was largely responsible for creating the "Taiwan miracle" that appears as a testament to capitalist development in the economics literature. This chapter also characterizes how the KMT government coordinated the petrochemical industry to prioritize oil's material value in response to the OPEC oil crises of the 70s, creating a path of upstream development while simultaneously pursuing para-diplomatic relations with the US and Middle Eastern countries to secure access to oil feedstocks and counterintuitively expanding the scale of production. It is this process and response that was largely responsible for the industrial coordination of Taiwan's modern synthetic materials industry.

The second chapter looks more closely at how the legacy of this development has created a fossil economy oriented toward materials, where specific materials are prioritized for value addition in their use as export technologies. This chapter overviews how the refining of oil creates both fossil fuels and yields material feedstocks as a byproduct, as well as how these byproducts came to fill vital roles in the production of key technologies, in which semiconductors, electric vehicles, and wind turbines are overviewed as key examples. In part, the ubiquity of plastic products allows for these materials to appear abstracted from its material origins, while fueling the plastic 'imaginaries' that can create techno-solutions to the crisis of carbon emissions. This ubiquity has also led to petromaterials becoming stand ins for many of the natural resources produced on plantation economies, and now serve as difficult to undo technological fixes woven into all commodity production. Viewed through Formosa Plastic's involvement in the production of materials technologies, this chapter questions how the the solutions to the crisis of carbon emissions from fossil fuels are materially constrained and enabled by the design capabilities of petromaterials, as their ubiquity and technical specificity prevents any alternatives from being feasible.

The third chapter examines many of the problems associated with widespread petromaterial use and petrochemical production, including the crisis of plastic and pollutant leakage from a greater system of petrochemical use. A series of three ethnographic essays explore how the petrochemical industry externalizes waste, including the limits of circularity in electronics recycling, widespread microplastic pollution, and air pollution and their effects on the health of fenceline communities. This chapter also postulates on how this production process, not only externalizes waste, but inculcates communities and ecologies into petromaterialism without alternative.

The concluding chapter addresses the legacy, ubiquity, and toxicity of the petrochemical industry within the degrowth movement. Through exploration of the obstacles to systems redesign due to the social reliance on and infrastructural path-dependency of petrochemical use, I examine how the process of undoing technological fixes created by petromaterials imply challenges for redesign of sociotechnical orders. This conclusion interrogates what it would take to redesign society in a way that could either do without petromaterials, or account for their impact in a future oil world. Ultimately, this dialectical process of degrowth aims to interrogate the existing reality provided by ubiquitous petromaterials and envision an alternate social system that can negotiate the rifts that are currently ameliorated by petromaterials.

A. Political Petromateriality

The material implications of oil amidst calls for a decarbonized future are best understood through careful study of the past and present. These historical conditions frame the occasionally unfathomable ubiquity of petromaterials in the modern world order as a historical invitation of oil into the objects of society and demonstrate political petromateriality. This literature review focuses on scholarship that examines the materiality of oil and its implications in the modern era, and references a greater debate within ecological-Marxism on the precise relationship possible between technology and nature, which will be explored in greater detail in the concluding chapter.

As a foundational text, Mitchell's (2011) *Carbon Democracy* outlines the historical conditions by which the transition from coal to oil served as the material basis for a new conception of the economy that could grow without limits. The relative abundance and ease of transport of oil allowed it to serve as a conceptually inexhaustible resource to supply energy and material without restrictions. The materiality of oil allowed it to serve as the bridge between the physical limits of the spatial and material processes of the 19th century and a new conception of economic growth. Advances in the chemical processing of oil feedstocks and the rise of synthetic materials represented the technological conditions that could ameliorate the limits of any resource.[17] From this petromateriality, technology and the economy could exist in the abstract, as unconstrained, unlimited functions of material growth.

This line of inquiry has recently been continued by the work of Adam Hanieh (2021) who examines more closely the historical conditions of oil as a material specifically. As petromaterials replaced wood, glass, paper, rubber, fertilizer, cotton, and a huge array of other naturally derived substances, the petrochemical revolution after the second world war enabled a "synthesization of what had previously been encountered and appropriated within the domain of nature" becoming

[17] Mitchell, Timothy. *Carbon Democracy: Political Power in the Age of Oil*. Verso, 2011.139-141

"the literal raw material of commodity production itself."[18] He calls the making of this synthetic world a "missing piece in understanding the role of oil in contemporary capitalism" where "petrochemicals are the means through which oil has become woven into the very fabric of our social existence."[19] In the efforts of the United States to create a post-war reality that bolstered the benefits of capitalism, petromaterials were entwined into nearly all aspects of production, creating an ubiquity that obscures "how the basic materiality of our world rests upon the products of petroleum."[20]

Huber's (2013) *Lifeblood* reminds us that the "malleability and durability" of these products came to represent a "revolutionized" post-war American material life, and were essential for constructing a "'free' society in opposition to communism."[21] Petromaterials became entwined with every aspect of social existence, and oil companies capitalized on newfound uses in cosmetics, synthetic fabrics, medicine, construction, and especially in social orders of the automobile. These technologies, and the oil refineries that provided the basis for their materiality reproduced the "imaginary of an individuated condition, or 'life' that is improvable solely by one's own effort and entrepreneurial capacities," and in this way inseparable from oil.[22] The social orders of US oil allowed for a material justification that supported a limitless economy and technological sublime.

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[18]Hanieh, Adam "Petrochemical Empire" *New Left Review*, 130 (2021): 27

[19] Ibid, 27

[20] Ibid, 51

[21] Huber, Matthew T. *Lifeblood: Oil, freedom, and the forces of capital.* University of Minnesota Press, 2013. 85, 72.

[22] Ibid, 64-5

As these standards of living and modes of production proliferated to other parts of the world, these refineries and massive interlinked petrochemical facilities now provide the materiality of the design criteria of new technological fixes. Within the legacy of this materiality, Hanieh writes that:

> "it is conceivable that some of the demand for oil and gas as an energy source can be reduced through alternative technologies and improved energy efficiencies—such as solar, wind or electric vehicles—but there is no way of imagining a future without oil as long as petroleum remains the fundamental material basis of commodity production."[23]

This is in part why energy technologies are instructive for describing the "paradox" of synthetic materials, as petromaterials "have come to define the essential condition of life itself" while they became a normalized, abstracted part of daily existence. Instead of envisioning decarbonization technologies solely as a direct challenge to a world order enabled by fossil fuels, new technologies and their reliance on petromateriality also allow existing social orders of oil to persist into future energy systems, albeit in different orientations.

At present, the shift to a new industrial system is limited by the infrastructural path-dependency of petrochemical infrastructure itself. Authors such as Frederic Bauer have dedicated recent work into understanding how path-dependency in the petrochemical industry brings challenges to decarbonization, detailing how carbon emissions and plastic use are "locked-in" to the logics and infrastructure of petrochemical production, making even theoretical intervention difficult. Bauer et al. (2022) details how the integrated design of the physical infrastructure of petrochemical plants make them difficult to retrofit or cease operations, creating a

[23] Hanieh, "Petrochemical Empire," 50

certain amount of interdependence that prevents alterations within one aspect of the system.[24] They discuss how the modern economic feasibility of petrochemicals relies on economies of scale, both entrenching a certain amount of petromaterial production and creating the proliferation of increasingly larger petrochemical facilities through competition.[25] Furthermore, they point to institutional lock-ins that limit regulations on the petrochemical industry and its products, as many of the major companies globally are directly or indirectly state owned and thus invested in their economic success.[26]

Alice Mah's recent ethnographic works (2019; 2021a; 2022; 2023) demonstrate how these lock-ins are acknowledged and enabled within the industry itself, and how certain environmental rhetorics for improved management lose their potency. Her work details how strategies for circularity within the petrochemical industry have simultaneously suppressed the agenda of the circularity design movement while continuing to enable a "take-make-waste" pattern of growth and ignoring the thermodynamic necessities of plastic recycling.[27] Mah's robust, global study of the sociotechnical conditions of the contemporary petrochemical industry demonstrates its intimate understanding of petrochemical's essential role in modern society, and also clearly shows the arrogance and brazenness by which the industry is resistant to change.

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[24]Bauer, Fredric, Tobias D. Nielsen, Lars J. Nilsson, Ellen Palm, Karin Ericsson, Anna Fråne, and Jonathan Cullen. "Plastics and climate change: Breaking carbon lock-ins through three mitigation pathways." *One Earth* 5, no. 4 (2022): 361-376. 364; see also Tilsted et al. 2023

[25] Bauer et al. "Plastics and Climate Change" 363

[26] Ibid 367

[27]Mah, Alice. "Future-Proofing Capitalism: The Paradox of the Circular Economy for Plastics." *Global Environmental Politics* 21, no. 2 (2021): 122

Each of these authors contribute vital context to a general debate for the feasibility of ecological modernism. Ecological modernism (from here on ecomodernism) can be defined as an environmental ideology that relies on technological development to manage anthropogenic impacts on the environment. This version of techno-optimism envisions that technology's progress can one day decouple the growth of the economy from a greater environment. While ecomodernism is often criticized for its fetishistic or deterministic view of technology as something that progresses independent of social conditions, a precise relationship to technology and the resource appropriability provided by capitalist extraction is much more difficult to calculate. In many examinations of how to ameliorate the 'irreparable rift' of appropriated value through capitalism, varying interpretations of Marx and degrees of emphasis on technosolutions are presented binarily. On one side are advocates of "prometheanism" for the wholesale appropriation of the technological benefits of capitalism to mitigate its own ecological crisis. On the other, advocates for "degrowth" champion reducing consumption, instead "restoring the radical abundance of communal wealth" generated from the newfound value in formerly appropriated resources and labor.[28]

The question of political petromateriality asks whether or not the materials of the design solutions of ecomodernism can successfully mitigate their own impact at all scales necessary, and how precisely degrowth can grapple with the simultaneous legacy, ubiquity, toxicity, and utility of petrochemicals. As petromaterials have become entwined into all aspects of modernity, physically

[28] Saitō, Kōhei. *Marx in the Anthropocene: Towards the Idea of Degrowth Communism*. Cambridge ; New York, NY: Cambridge University Press, 2022. 232

embedded in all life, and ensured in a carbon-free or carbon-full world, what negotiations must be had with this everpresence?

B. The Energy Transition meets the Plastic Transition

The International Energy Agency (IEA) report "The Future of Petrochemicals" traces the pressure of reducing carbon emissions on plastic and fertilizer production within the context of several climate scenarios. Globally, 14% of all oil and 8% of all natural gas is consumed by the petrochemical industry, half of which goes to the material demands (as opposed to energy) for the manufacture of feedstocks for commodities, mainly plastics and fertilizers.[29] However, the energy used during petrochemical production yields 85% of its carbon dioxide emissions, whereas chemical material processing yields 15%.[30] As the fastest growing consumer of oil, rising plastic demand is causing the petrochemical industry to become "the largest driver of global oil consumption."[31] Even amidst global efforts to reduce fossil fuel consumption, the production of petrochemicals is expected to grow dramatically by 2050.[32]

The production of plastics emits greenhouse gas, and lots of it. Much of it is carbon dioxide emitted from combustion of fossil fuels for the energy necessary to heat naphtha to a temperature high enough to 'crack' chains of hydrocarbons into materials used in downstream processes.

[29] IEA "The Future of Petrochemicals," 14, 18
[30] Ibid, 32.
[31] Ibid, 11
[32] Ibid, 72. The per capita production of key plastics would increase nearly 30% under the Reference Technology Scenario, which is a modeling projection used by the IEA to predict likely scenarios for the decarbonization of the energy system.

Petrochemical production, by some accounts, amounts to 27.1% of energy demands in Taiwan, and in the massive Formosa Plastics Sixth Naphtha Cracker (Liuqing) this energy is produced from coal.[33] Though Liuqing is in the process of switching over to natural gas, this industry is still decades out from getting close to phasing out fossil fuels, let alone reaching net-zero carbon goals by 2050. While Formosa Plastics Group has announced tentative plans for an industrial algal sinking carbon capture plant at Liuqing as part of their net-zero strategy, this technology does not address the disproportionate burden of industrial air pollution for communities living near the facilities.[34] The petrochemical industry in general is one of the last that is expected to decarbonize, meaning that air pollution from fossil fuel sources will persist longer than in other industries, despite being one of the world's largest sectors for energy consumption.[35]

As Lavers et al. (2022) have shown, mitigation of the plastic crisis and the climate crisis are occasionally presented as diametrically opposed to one another.[36] Their review of literature points to a disturbing trend in which experts disregard the impending danger of the plastic crisis as a necessary evil for preventing the irreversible damage of climate change. In reality, climate change and microplastics each present unique technical challenges in their remediation, but their anthropogenic origins are indisputably intertwined. If we think of petrochemical production as one system, in which oil, gas, and coal are inputs and fuel and petromaterials of all sorts are

[33]Chou, Kuei-tien, David Walther, and Hwa-meei Liou. "The conundrums of sustainability: Carbon emissions and electricity consumption in the electronics and petrochemical industries in Taiwan." *Sustainability* 11, no. 20 (2019): 5664.

[34]Formosa Plastics Group, "Formosa Plastics Net Zero Strategies"; see Appendix, Disaster STS

[35] IEA, "The Future of Petrochemicals"

[36] Lavers, Jennifer L., Alexander L. Bond, and Charles Rolsky. "Far from a distraction: plastic pollution and the planetary emergency." *Biological Conservation* 272 (2022): 109655.

outputs, it is clear that the emission of carbon and plastic waste are both leakages from a system that is not able to account for its outputs. While these issues should be considered as part of the same system that relies on a type of externalization of waste, the value of plastic and its unclear ecological limits allow the major problems of plastic waste to take lesser priority.

While climate change mitigation efforts aim to de-link the production of energy from carbon intensive energy sources through development of renewable energy technology, the petrochemical system of material production is currently without a suitable substitute or circularity strategy. Bioplastics, while showing promise in circularity, would require large swathes of industrial agricultural production to be dedicated to their material input. Under the Clean Technology Scenario outlined by the IEA, substitutive bioplastics would require more than half of the world's sustainable biomass for primary chemical consumption.[37] True circularity of traditional plastics is also highly unlikely: up until 2015 only 9% of the 6.3 billion tons of plastics made have been recycled, and 98% of single use plastics manufactured come from virgin feedstocks.[38] This is in part due to the chemical complexity of modern plastics, each type with a unique chemical composition that requires a different recycling process. Recycling rates are also often clouded by misrepresentation of pyrolysis and trash combustion as achieving system circularity.[39] Meanwhile,

[37] IEA, "The Future of Petrochemicals" 114, via Bauer et al "Plastics and Climate Change" 369

[38] Geyer, Roland, Jenna R. Jambeck, and Kara Lavender Law. "Production, use, and fate of all plastics ever made." *Science advances* 3, no. 7 (2017). via Tickner, Joel, Ken Geiser, and Stephanie Baima. "Transitioning the chemical industry: the case for addressing the climate, toxics, and plastics crises." *Environment: Science and Policy for Sustainable Development* 63, no. 6 (2021): 4-15.

[39] Bauer, Fredric, Tobias D. Nielsen, Lars J. Nilsson, Ellen Palm, Karin Ericsson, Anna Fråne, and Jonathan Cullen. "Plastics and climate change—Breaking carbon lock-ins through three mitigation pathways." *One Earth* 5, no. 4 (2022): 361-376.

plastic waste has broken down into microscopic pieces that have become embedded in nearly all aspects of life on earth.

It is difficult to make plastics without producing toxic byproducts. Mah (2023) mentions encountering the "'two-for-one principle'" in which "less-toxic petrochemicals cannot be produced in isolation from the more-toxic ones" as "that chemical processes involve generating by-products, all of which need to find places to go, whether into new processes and products, or into waste disposal."[40] Similarly, smaller scale approaches to plastic production are difficult because other products are reliant on by-products as feedstocks for their production. To make chemical production economically profitable, base chemicals must be refined at scale to lower costs, and subsequent series of reactions can produce a spread of other chemicals with specific technical applications.[41]

The petrochemical industry also suffers from several "lock-ins" that inhibit decarbonization at multiple stages in its production process. Bauer et al. (2022) explains that a carbon lock-in is a "strong path-dependency connected to the use of fossil fuels across many domains," including within the "'techno-institutional complex'" that creates technology with the goal of "maximizing returns using fossil resources and globalizing markets for fossil commodities."[42] The production of technology within the petrochemical industry thus implies a certain amount of plastic production and carbon emissions despite decarbonization of its power source, in the path-dependency of its infrastructure, transportation systems, interreliance and connectivity between series of chemical

[40] Mah, *Petrochemical Planet* 104.
[41] Tilsted et al. "Ending Fossil-Based Growth," 7
[42] Bauer et al. "Plastics and Climate Change," 361-3

production, and consumption of plastic products deemed socially essential. Especially in downstream applications, plastics are locked-in use by industries essential for the economies of many states and the function of the life of modernity.

Developing technology that offset or reduce these carbon lock-ins is compatible with the ideology of the petrochemical industry's techno-instutional complex. Renewable energy technologies, carbon capture and storage, oil-to-chemical refining are all strategies that are being pursued by actors within the fossil fuel industry. These technologies reduce the amount of carbon emission from fossil fuels, but will not subsequently produce a reduction in petromaterials, making their production compatible with existing lock-ins. This is why so many oil companies are subsequently producing renewable technologies. It's not just greenwashing and hedging their bets: the petrochemical industry has the technological expertise, the upstream materials, and a proven business model of downstream value addition for production of consumer technologies. Development of new renewable energy technologies is constrained to a literal *material* substratum of technological development, in addition to an energetic one.[43]

The role of oil as a material necessitates understanding plastic as a type of material technology, where oil's chemical alteration can create specific qualities to substitute for the matter of non-fossil material systems.[44] The widespread adoption of petrochemicals and plastics became a technological fix that grew to substitute material demands typically supplied by plantation economies, such as

[43] Malm uses the term "material substratum" to refer to the energetic qualities of fossil fuels being inculcated in modern society, whereas I expand this term to include the literal petromateriality of the material substratum. Malm, Andreas. Fossil capital: The rise of steam power and the roots of global warming. Verso Books, 2016.

[44] Rosenberg, Nathan. "Chemical engineering as a general purpose technology." *Studies on Science and the Innovation Process* (2009): 303-328.

cotton fabrics, natural rubber, guano for phosphorus fertilizers, among others. New arrangements of alternative technological fixes thus enact unique and geographically specific spatial orders, often with toxic effects on fenceline communities at sites of extraction and production,[45] in order to bridge the contradictions of the social formation originally produced for and by fossil energy.

As Sovacool and Monyei (2021) remind us, the mitigation of climate change through decarbonization is an important cause for preventing millions of air-pollution related deaths from fossil fuel use.[46] One can also predict that the reduction in carbon would save countless lives through the avoidance of complete climate breakdown. Yet, the reliance on petromaterials constrains the ability to innovate materially distinct technologies and reduce long term reliance on the oil industry. The energy transition increasingly relies on chemicals derived from the refining of fossil fuels, in the form of thermoplastics, fibers, resins, or high purity chemicals. Other lock-ins in packaging and transportation drive increased demand for petrochemicals globally. The petrochemical industry has the expertise and economic interests to expand their production and provide the materials that are required by modern society, creating more toxicity and adding to the flow of plastic material waste. Despite the framing of the energy transition, this industrial transformation will continue to rely on the appropriation of oil's material qualities, and constrain the solutions to ecological problems to genuinely ameliorate the 'rifts' of resource appropriation.

[45] Sovacool, Benjamin K., Andrew Hook, Mari Martiskainen, Andrea Brock, and Bruno Turnheim. "The decarbonisation divide: Contextualizing landscapes of low-carbon exploitation and toxicity in Africa." *Global Environmental Change* 60 (2020).

[46] Sovacool, Benjamin K., and Chukwuka G. Monyei. "Positive externalities of decarbonization: quantifying the full potential of avoided deaths and displaced carbon emissions from renewable energy and nuclear power." *Environmental Science & Technology* 55, no. 8 (2021): 5258-5271.

The inability to also propose alternative sociotechnical orders as solutions to energy and material disparities perpetuates an ideology of ecomodernism and falls well within the existing orders of global capital.

C. Taiwan, the Petrochemical Kingdom (*shihua wangguo*)

Whether it be the Petrochemical Kingdom or the Silicon Island, Taiwan's economic transformation over the last century is called nothing short of a "miracle" in the economics literature of the 70s and 80s. A densely populated island and de facto nation off the southeast coast of China, Taiwan's economic growth within relatively resource constrained borders appears as a testament to the science of capitalism. As one of the "four tigers" of post-war East Asian economic growth, this pattern of growth amongst port cities of Hong Kong and Singapore, and the former Japanese colonies of South Korea and Taiwan came to represent a viable path of industrialization for developing countries. Today, Taiwan is known for its highly specialized electronics manufacturing, where its foundries produce the vast majority of the world's semiconductors, creating a global bottleneck in the electronics supply chain that provides a "silicon shield" to Taiwan amidst threats of forced reunification with China. What this common narrative often ignores is the role that the United States has played in providing expertise, aid, and a consumer market for export products, in exchange for strategic military strongholds amidst the Korean and Vietnam wars and geopolitical tensions with China. Within this politicized and historicized reexamination of the origins of Taiwan's petrochemical industry, the economic mechanisms of "miraculous" growth and technological development were serviced by the geopolitical interests of the United States, and composed materially of oil.

The interrelations of petromateriality and technology that are the focus of this thesis are studied via a through-line case study of Formosa Plastics Group, the first private petrochemical company in Taiwan and one of the largest globally. This case study serves both as representative of the conditions of private petrochemical capital and its historical relationship with the state in Taiwan, but also as a use case for understanding the interrelationship between technology and petromaterials. Formosa Plastics is a highly diversified petrochemical conglomerate that does everything from refine oil to manufacture microelectronics through its various subsidiaries. Petrochemical conglomerates tend to also have stakes investment in downstream production, but ultimately Formosa's are relatively easy to study compared to other petrochemical producers as the conglomerate tends to share a similar name and branding across its branches. Compared to US oil companies who frequently try to hide their operations and will change their company name at the whiff of the slightest controversy, perhaps there is a relative pride in the role that Formosa has played in the development of Taiwanese private capital. Formosa thinks of themselves as the bringers of modernity to Taiwan, and so is not afraid to hide its history, bolstering three distinct museums dedicated to FPG's history, products, and contribution to society. However, where they will try to skirt responsibility is their contribution to global pollution, workplace accidents, and pollution in communities and ecologies surrounding their plants.

The reality of the production of petromaterials, even for this vertically integrated and high value addition economy, is that many communities are exposed to cancer-causing levels of pollution without their consent. The massive petrochemical complexes throughout Kaohsiung, Mailiao, and a variety of other facilities scattered throughout urban, densely-populated, industrial corridors expose residents to unsafe levels of air pollution and high risk hazards that create unequal zones of toxic exposure. The work of researchers such as Paul Jobin and Wen-ling Tu have helped contribute to justice for fenceline communities who repeatedly endure this exposure, but ultimately the harms of proximity to petrochemical production are characterized by a "slow violence" to which it is difficult to attribute causation.[47] Additionally, the relationship between workers and petrochemical facilities is difficult to grapple with, as these polluters bring relative wealth to these communities through employment.

However, Taiwan's unique political condition as a fully independent but internationally unrecognized democratic state, as well as the living memory of modern history's longest endured authoritarian state and multiple regimes of colonization, creates a social dynamic that must grapple with environmental limits in the greater geopolitical contention of fragile US hegemony. Questions poised by calls for degrowth and deimperialization, as well as demands for environmental regulation, are met with anxieties of invasion and limits on national determination. Within state struggles for global legitimacy, alternatives to global economic trade and high technological

[47] Tu, Wen-Ling. "Combating air pollution through data generation and reinterpretation: Community air monitoring in Taiwan." *East Asian Science, Technology and Society: An International Journal* 13, no. 2 (2019): 235-255.; Jobin, Paul. "The economy of compensation and struggle for reparation: The case of Formosa Plastics in Taiwan." In *Rethinking Post-Disaster Recovery*, pp. 25-48. Routledge, 2021.; Nixon, Rob. *Slow Violence and the Environmentalism of the Poor*. Harvard University Press, 2011.

production are not unfathomable, but each attempt at regulation reposes an existential unknown. In this way, the limits of extrapolation to the global scale are met with the historically specific conditions of power and identity.

While the focus of this study is on Taiwan, it is informed by the emerging dynamics of a global dependence on petrochemical industry for material production, and a shift within the industry to research materials and technologies as a compatible business strategy with limited access to fossil fuels. In this way, Taiwan presents a distinct case study for looking at the future of oil in the energy transition, in that the petrochemical industry has been historically and geographically detached from the traditional, extraction-oriented oil industry. Nearly all fossil fuel feedstocks are imported into Taiwan, where they are then refined and processed into fuel oil and petrochemical products. The petrochemical industry in Taiwan is thus centered on technological development and midstream value addition to petrochemical products, in which networks of product-diverse corporate conglomerates seek to find downstream technical applications for petrochemical products.

This perspective allows for the study of the emergence of a highly technology focused industry in Taiwan to serve as a speculative use case for the developments in global petrochemical industries to accommodate highly varying degrees of climate change mitigation. If pressures to decarbonize are internalized in petrochemical operations, strategies of value addition to petrochemical products and downstream linkages to technology production will serve as an expanding role for material applications of oil and gas. The ingenuity in adding value to what has historically been a byproduct of fuel production has created local and global technosocieties that are reliant on the malleability and technical specific plastics for development of technology as solutions to societal problems.

D. Methods

The approach to this project is an effort to understand the role of the petrochemical industry within the energy transition, through an historical and ethnographic perspective on dynamics within petrochemical industrialization and technology production. This draws from Burawoy's extended case method, in which a reflexive method of scientific understanding is based on participant observation.[48] In this application, a historical understanding of the coordination of global state and oil industry politics is necessary for observing how the production and promotion of technology is nested within a greater production of material conditions. From this basis, a new understanding of congruent capital interests is made more easily visible, in turn informing how decisions over material production are made based on technological demands and constraints. These understandings, viewed through the lens of Taiwan and Formosa Plastics Group, are based on archival research, appropriation of exhibits in corporate museums, reexamination of empirics from the wide range of economics literature on Taiwan in the late 20th century, and inquiry into the physical characteristics of material and technology production, typically as advertised by the companies themselves. By tracing the flows of material and how the spaces of industrialization were transplanted and produced within an oil based world order, the production of technology becomes

[48] Burawoy, Michael. "The extended case method." *Sociological theory* 16, no. 1 (1998): 5-6

historically linked with the global dynamics of extraction politics and war, which in turn produced an environmental ethos.

This research process has also been informed through participation in the Formosa Plastic Global Archive, an effort to catalog and characterize Formosa's environmental and social impact across its many sites of production.[49] The archive includes a wide range of documents, images, interviews, and testimonies contributed by activists and researchers across sites in the United States, Vietnam, and Taiwan. Not only has this rich collection been an invaluable resource in generating a holistic understanding of the struggles of communities for voice within the process of petrochemical production, but it has also served as a generative linkage between researchers involved in the FPGA and other collections hosted through the Disaster STS project through the Platform for Experimental and Collaborative Ethnography. The metaprocesses of active contribution and archival analysis help create engagement across spaces and temporalities, allowing for ethnographic research that strays beyond insularity and create new linkages to understand the complexities of the double-binds of petrochemical production.[50] This thesis has examined artifacts in and contributed artifacts to the archive, which are detailed in the appendix and referenced throughout the thesis.

This ethnography is within the greater context of how the generalities and terms of environmentalism are informed, diluted, lost, or otherwise affected by the social realities of a landscape of industrial material and energy production. This process of understanding these

[49] See Appendix, Disaster STS

[50] Fortun, Kim. *Advocacy after Bhopal: Environmentalism, disaster, new global orders*. University of Chicago Press, 2001

tensions ethnographically necessitates reflexively interrogating a preexisting understanding of how fossil industries operate, and how they are perceived by and affect communities living in proximity. This method necessitates a wide range of "encounters and interactions" to discern "zones of cultural friction" as transient moments in which "words mean something different across a divide even as people agree to speak."[51] To understand the ambiguities of technology, its production within a techno-historical process of petrochemical industrialization, and the effects of this on proximal communities, a "patchwork" combination of information is necessary. This has included attending technology exhibitions to promote the semiconductor, plastic, and green energy industries in Taiwan, interviews with journalists and academics, working alongside established research and advocacy groups, site visits to industrial parks, and participant observation and interview in communities affected by petrochemical and energy technology developments.

[51] Tsing, Anna. *Friction: An Ethnography of Global Connection.* Princeton University Press, 2005. xi

II. Petromaterial Conditions: Origins of the Petrochemical Industry in Taiwan

*Pictured above are two paintings of the founding brothers of Formosa Plastics Group. Founder Y.C. Wang (right) is pictured in front of his annually mandated company-wide recreational runs, with the text "hard work and simple business" (*動勞樸實 *donglaopushi) pictured above. Brother and longtime head of Formosa Chemicals and Fiber, Y.T. Wang (left) is pictured in front of Liuqing and a large golf course, purportedly his favorite activity. These paintings hang in the Formosa Plastics Museum in Linkou, Taoyuan, Taiwan*

This chapter explores how the introduction of the US aid program to Taiwan from 1950-1965 encouraged the establishment of Formosa Plastics Corporation (FPC) and production of polyvinyl chloride (PVC). This led to the growth of a petrochemical industry that was essential for Taiwan's developmental trajectory and a vital component for modern military function and technological development. Through an analysis of US aid developmental discourse, this chapter examines how the origins of FPC and the petrochemical industry in Taiwan are rooted in wartime economic functions, and US interests for containing the Chinese Communist Party (CCP) control over East Asia. Understanding the industry's origins highlights the combination of development and military goals, and how these origins influenced the development of the early semiconductor industry and Formosa's early research into electric vehicles in response to the oil crisis, which is detailed in Chapter 2. Amid environmentalist calls for degrowth, as well as increased reliance on technology in mitigating climate change, a review of the historical origins of the industry and its ensuing dynamics of expansion shed light on how fossil fuels and materials became embedded in society, leading to the 'chemical century.'

The origins of this industry are important to understand for two main reasons. First, the production of petrochemicals has historically been explicitly tied to the demands of the military. The production of fuel oil yields byproducts that became the feedstock for many of the synthetic materials that replaced natural materials grown on plantation economies or extracted from the earth. Especially during the second world war, the United States, Japan, and Nazi Germany developed these materials to improve their military capacity in response to restrictions of materials from former colonies.[52] This material technology then grew to provide the materiality of "the good life" associated with the petromaterial conditions of liberal economies, entrenching this technological fix as the basis for modern liberal economies.[53] This historical understanding is essential in the context of modern plastic discourses, as it emphasizes exactly how the polluting and domineering aspects of petrochemical production have become an essential part of the fabric of modernity, and links back to how material served to refute communist expansion and legitimize an authoritarian regime in Taiwan.

[52] Hanieh, "Petrochemical Empire"
[53] Huber, *Lifeblood,* xx

The second reason is that the development of the industry in Taiwan is rather distinct from other strategies of petrochemical development due to its "reverse integration" pattern of import substitution. In most petrochemical facilities, oil is distilled into a set of base chemicals alongside the so-called 'natural' production of fuel from crude oil. As a general trend for the global petrochemical industry, old and new chemicals are developed from these byproducts and downstream applications are later designed and marketed for their use.[54] Taiwan instead first established export-oriented downstream production through aid from the US, then later expanded its upstream production in response to demonstrated uses of petrochemical products. While later petrochemical complexes such as FPG's Liuqing are characterized by more upstream integration, the majority of Taiwan's petrochemical development specializes in supplying specific downstream chemical products from isolated fossil inputs. The implications of this shift may imply a specific ability for the contemporary Taiwanese petrochemical industry to respond and coordinate specific materials for downstream technology use, as they have historically capitalized on oil's material value.

Taiwan's separation from reserves of fossil sources have necessitated a specific display of paradiplomacy relations with countries in the Middle East as well as the US. The KMT government scrambled to secure access to upstream oil sources in Saudi Arabia at the same time that it incentivized the expansion of midstream petrochemical processing to guarantee the longevity of synthetic material supply to its fledgling export industry. In Taiwan, the KMT

[54] Hanieh, "Petrochemical Empire," 43-4

government implemented specific industrial policies targeting the petrochemical industry toward technological development. These actions can be seen as a way of attempting to secure feedstocks for an economy based on the materiality of oil, while pursuing higher-value addition. These series of events may highlight a certain type of path-dependency that was brought about by the early export-industry, where a petroeconomy supplemented for the resource constraints in Taiwan, largely brought about by the synthetic materials created from oil. This materiality, in addition to energy, provided mechanisms of control for the KMT in Taiwan that created the ubiquitous materiality of modern plastic.

A. Wartime Production of Petrochemicals and the Rise of Consumer Plastics

During the second world war, significant advancements were made in US petrochemical technology, primarily to supply high octane aviation fuel to the US air force. Chemical engineering programs at US universities, namely the Massachusetts Institute of Technology MIT, were an essential component for technological research into increased efficiency in the refining process.[55] With the invention of fixed bed catalytic cracking and olefin refrigeration recovery in the later 30s, new technological advancements were being invented to support increased fuel yields from crude oil refining.[56] By the invention of fluid catalytic cracking in 1942, production capacity of the average catalytic cracker refinery could yield 2500 barrels of aviation fuel per day, with 6500 barrels of residual heavy fuel yielded as byproducts.[57] Concurrently, Japanese control of natural rubber

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[55] Rosenburg, "Chemical Engineering as a General Purpose Technology"

[56] Spitz, Peter H. *Petrochemicals: the rise of an industry*. Wiley, 1988.. 119-120

[57] Ibid, 135

plantations in Southeast Asia stressed the US government to create synthetic rubber manufacturing facilities. These new plants could use salvaged styrene and butadiene from the new refining process to produce an adequate rubber substitute, with wartime pressures necessitating open exchange of technological information between major US chemical companies.[58] This government-led research and advancements in petrochemical technology leading prior to and during the second world war yielded necessary materials for the US military, but in the post-war period the purposes of these facilities became much less clear.

Ample petrochemical feedstocks and infrastructure leftover from wartime production of fuel oil incentivized the mass production of plastics in the postwar period, with plastic consumption increasing from 20 million pounds of thermoplastic in 1940 to over 500 million pounds by 1950.[59] Demands for consumer goods and household appliances in the post-war period incentivized further research in potential uses of petrochemical products to meet material demand. Thermoplastics such as PVC were a viable substitute for other materials, primarily made out of ever cheaper ethylene byproduct butadiene, and hydrogen chlorine made from the production of caustic soda, all of which were produced at large scales from the wartime effort.[60] PVC, as well as a wide variety of other petromaterials, could be used to cheaply produce a huge array of consumer products, such as single-use packaging and containers, textiles, home appliances, construction materials, and components for automobiles and airplanes. The later widespread adoption of plastic

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[58] Ibid, 143-145

[59] *Modern Plastics* January 1951, via Spitz, *Petrochemicals*, 229; Rosenberg, "Chemical Engineering as General Purpose Technology," 318

[60] Spitz, *Petrochemicals*, 265

products in the US emerged from postwar social needs and military surplus, repurposing large scale production from wartime corroboration between oil companies, researchers, and the US government. At the same time, US companies like DuPont, Monsanto, and Union Carbide were building increasingly complex production facilities that utilized refinery byproducts as feedstocks, in areas close to fossil fuel refineries in Louisiana, Texas, and West Virginia.[61]

This newfound petrochemical industry came out of the excess byproducts for the production of wartime fuel oil, creating new chemical technologies to salvage materials that could provide uses for the military or be sold as material for consumer industries. The development of this technology came primarily from state-organized technological sharing and wartime fuel production that generated surplus naphtha feedstocks for the input of the chemical sector. These plentiful byproducts from wartime fuel demand led to the widespread use of plastics after the second world war would have come about much slower, as well as the technological knowledge used to establish petrochemical facilities globally.

B. Post-war Industrialization 1945-65

In his inauguration address in 1949, President Harry S. Truman outlined a plan for "world economic recovery" to "strengthen freedom-loving nations against the dangers of aggression" of the "false philosophy of communism."[62] This speech followed the Economic Recovery Act of 1948, later known as the Marshall Plan, a schematic for the reindustrialization of Europe in the

[61] Ibid, 308

[62] Harry S. Truman, Presidential Inaugural Address, January 20, 1949 *Harry S. Truman Library & Museum*. Accessed: https://www.trumanlibrary.gov/library/public-papers/19/inaugural-address

wake of the second world war. In addition to trade liberalization that created markets for US products, the Marshall Plan expanded the refining capacity of Europe by a factor of five, entrenching patterns of increased oil consumption.[63] Oil imports in Marshall Plan countries were supplied solely by the Seven Sisters, who had come to own 85 percent of all petroleum reserves and dominated the extraction and production of crude and refined oil.[64] These oil imports were in turn paid for by US dollars given to post-war states through aid via the newly created Economic Cooperation Administration (ECA), which imported oil extracted by these same companies in the Middle East.[65] In joint ventures between the oil majors and local manufacturers, Europe's post-war petrochemical industry grew adjacent to US oil interests.

As Mitchell and others have pointed out, Truman refused to institute a version of a Marshall Plan in the Middle East, but instead implemented the Point Four Program that favored technical advising over capital infusions in developing states.[66] However, in post-war East Asia, a short term plan of economic recovery was also overseen by the MacArthur occupying government in Japan,. As the Chinese Civil War continued between the CCP and the Kuomintang (KMT) nationalist government that would later become the ruling party of Taiwan, interest in bolstering the economy of Japan and its former colonies became paramount to US military interests. This shift in policy around 1947, often called the "reverse course" was characterized by US direct aid to economic industry rebuilding and rooting out of communist sympathizers in both Japan and its former

[63]Painter, David S. "Oil and the Marshall plan." *Business History Review* 58, no. 3 (1984): 359-383.; via Hanieh, "Petrochemical Empire," 40

[64] Hanieh, "Petrochemical Empire," 38, 41

[65] Painter, "Oil and the Marshall plan," 363

[66] Mitchell, *Carbon Democracy*, 120

colonies of Taiwan and Korea. As the war in China continued and the KMT began their retreat to Taiwan, a regime of de facto aid to establish a military stronghold amidst burgeoning war. This program included technological expertise that advised the creation of Taiwan's early export industry, including the establishment of Formosa Plastics as an example of private enterprise within state-owned oil refining capacities.

Replica bags of raw PVC materials produced by the fledgling Formosa Plastics, on display at the Formosa Wang Brothers Park in Kaohsiung, Taiwan.

1. US Aid to Taiwan and the Establishment of Formosa Plastics

After the second world war, US led aid programs and the Marshall Plan spurred the development or rehabilitation of oil refineries and petrochemical facilities in Europe and East Asia.

This time period also corresponded with the proliferation of engineering firms who were able to coordinate and establish petrochemical complexes and could acquire licenses for the use of US patents and technology.[67] Engineers and scientists who were essential for development of military technologies, such as Scientific Design Company established by former Manhattan Project researchers, were sent to Europe and Japan to establish new industrial facilities on behalf of the intellectual property of American companies.[68] In Japan, Scientific Design led technology transfers of ethylene oxide production knowledge (which is used to manufacture polyester) to Mitsui petrochemical and Mitsubishi Petrochemical, but the establishment of large scale refineries was prohibited by the MacArthur-led occupying government.[69] These facilities were instead temporarily reliant on cracking imported naphtha, presumably from the large refineries in the US and Japan, to manufacture petrochemicals.

In China, US oil companies were eager to enter joint ownership of oil refineries and sell surplus oil to the Chinese market and the KMT, but were met with frustration at the nationalization of oil resources through the formation of the state-owned China Petroleum Corporation (CPC). In 1946, US petrochemical companies expressed their dissatisfaction with the nationalization of oil refineries held as property by Standard Vacuum Oil.[70] Representatives of the company wished to create joint ventures with CPC for oil exploration, as well as to take over and manage the Japanese

[67] Spitz, *Petrochemicals*, 317
[68] Ibid 318-319
[69] Ibid 378
[70] "Interest of the United States in Fair Competitive Opportunity for American Oil Companies in China in View of Establishment of Chinese Government-Owned Oil Company" Oil. *Foreign Relations of the United States, 1946. The Far East: China Volume X* 1974. 1375; See Appendix, Historical Documents

Takao refinery in Kaohsiung, Taiwan.[71] On July 12, 1946, representatives of Standard Vacuum, California Texas Oil Company (Caltex), and Shell China met with Wong Wen-hao, Vice President of the Executive Yuan and Chairman of the Board of the newly formed CPC. The CPC allowed shareholders but had a policy discouraging foreign investment from private companies, frustrating oil companies who were uninterested with competing with the CPC as both "business competitor and as government regulatory body."[72] Instead of accepting the offer from the US oil companies, Wong opted to apply for a 5 million dollar loan from the US Import-Export Bank for the rehabilitation of the Japanese Imperial Army's Takao refinery in Kaohsiung, but was assured by John Leighton Stuart that funds would not be available for the development of "indigenous oil resources or refining ... imported crude products." [73] To this, Wong said that the interests of American oil companies might materialize through an agreement, but that the KMT should be free to enter deals with representatives of the Anglo-Iranian Oil Company or "other American oil companies."[74] While Caltex and Texaco eventually entered into joint agreements with the CPC to deliver crude to their Shanghai refineries at the Shanghai power plant, these deliveries continued until the CPC refineries were taken over by the CCP in 1949.[75] By the start of the Korean War in 1950, the US had initiated an oil embargo to halt all oil shipments to the CCP and North Korea and encouraged United Kingdom companies to do the same.[76] The CCP pushed the KMT army

[71] Ibid. 1376

[72] Ibid 1377, 1378

[73] Ibid 1383

[74] Ibid 1383

[75] "Problems of United States Consulates in areas Occupied by Chinese Communists" *Foreign relations of the United States, 1949. The Far East: China Volume VIII*. 1978. 960, 1156-7; See Appendix, Historical Documents

[76] "The China Area" *Foreign relations of the United States, 1950. East Asia and the Pacific Volume VI* 1950. 647-8; See Appendix, Historical Documents

and government to Taiwan, where the nationalist government would remain until the end of martial law in 1987.

After the KMT retreated to Taiwan, the tension between US private oil companies and the state-owned CPC continued through the 1950s. This was slightly ameliorated by aid shipments of fertilizer and petroleum redirected from the mainland to Taiwan. However, the goals of the newly formed Economic Cooperation Administration (ECA) to establish a 'free enterprise' industrial economy in Taiwan were at odds with the KMT's desire to maintain national control over key portions of its economy and bolster its military.[77] With the passing of Public Law 47 by the 81st Congress, the ECA began its 15 year program of economic and military assistance to Taiwan amidst wartime tension with the CCP and North Korea.[78] In order to implement and advise the development paradigm of US aid, the J. G. White Engineering Company was hired by the ECA to oversee construction of essential infrastructure for the KMT, bringing with it the technocratic expertise of petrochemical, industrial, and agricultural knowledge. J. G. White was one of the predominant civil engineering firms hired by the US government at the time, and had experience in constructing military infrastructure such as naval bases and airfields in California, as well as hydroelectric dams in Chile and irrigation projects in Sudan.[79] The ECA and J. G. White oversaw the reestablishment of state-owned factories to prewar production levels, particularly the textile

[77] Cullather, Nick. "“Fuel for the Good Dragon”: the United States and industrial policy in Taiwan, 1950–1965." *Diplomatic History* 20, no. 1 (1996): 6

[78] “The China Area” *Foreign relations of the United States, 1950. East Asia and the Pacific Volume VI* 1950. 277; See Appendix, Historical Documents

[79] Cullather "‘Fuel for the Good Dragon’" 6

industry that contributed to the export-oriented textile industry of the 1960s 'miracle' boom.[80] According to Cullather (1996), the ECA devised a plan to bring about a sort of "military Keynesianism" that could develop key sectors of the economy while supporting state monopolies that generated revenue straight to the KMT military budget.[81]

Much to the distaste of Standard Vacuum Oil, the ECA intimately supported the state-led growth of key industries in 1950s KMT Taiwan, including the petroleum industry. However, as anti-communist dissatisfaction grew with the state-owned development of oil refining capacity that was being overseen by J. G. White and its project director Valery S. de Beausett, US congress demanded to restrict aid to Taiwan until direct foreign investment (DFI) was made feasible. This prompted vice president Chung-jung Yin to pursue symbolic efforts of privatization amidst the irreconcilability of a laissez-faire wartime economy, which he said required "active participation of the government in the economic activities of the island."[82] To do so, de Beausett and Yin coordinated to forcibly bequeath certain industries to "hand-picked entrepreneurs."[83] This led to the establishment of Formosa Plastics Corporation (FPC), when Yin chose Y. C. Wang to take over the soon to be constructed PVC processing facility near the Takao refinery in Kaohsiung, which was established through J. G. White and ECA initiated import substitution.[84] FPC, one of the

[80] Ibid, 9

[81] Ibid, 11

[82] K. Y. Yin, "A Discussion of Industrial Policy for Taiwan,"; via Cullather, "'Fuel for the Good Dragon,'" 15

[83] Cullather, "'Fuel for the Good Dragon'" 18

[84] Ibid 18; Gold, Tom. *State and Society in the Taiwan Miracle*. Sharpe, 1984. 71; Wang Yufeng, "Old Bay, New Port - Excerpt," See Appendix, Disaster STS

largest petrochemical producers in the world as of today, exists as a product of US aid and KMT state-led development of US petrochemical technology.

By 1957 the PVC plant became fully operational, but still heavily relied on US adjacent trade networks (such as Japan oil refineries re-established by a Monsanto subsidiary during the MacArthur occupying government) to oil feedstocks for production.[85] The early PVC plant used ammonia and other chemicals left over from the Takao refinery in Kaohsiung, which were carted over by mule to the facility nearby. FPC began to see profit growth after they were allowed to join the export market for PVC, primarily to South Korea and the Philippines, and later Vietnam, Thailand, Hong Kong, and Iran.[86] The subsequent development of FPC subsidiary Nanya Plastics was established to produce rubber tapes and sheets, and other subsidiaries to produce raincoats, diapers, and plastic leather bags.[87]

C. Reverse Integration 1965-87

Reverse integration is the term used to describe Taiwan and the KMT's specific application of import substitution industrialization, where upstream and midstream petromaterial feedstocks are developed after the establishment of a downstream export industry. The early stages of the development of basic plastic material products for export created the material systems that later became the basis for industrial production of higher value added products. While Formosa's origins in PVC were possible only through imports of feedstocks and reuse of byproducts from

[85] Cullather, "'Fuel for the Good Dragon'" 18
[86] Wang, Yufeng, "Old Bay, New Port - Excerpt"
[87] Ibid, para. 20

other industries, by 1968 CPC established Taiwan's first naphtha cracker to manufacture ethylene. The first cracker was experimental and relatively inefficient at the scale of production, which prompted the expanded Formosa Plastics to call for a private facility as early as 1973.[88] They would later get their wish with the construction of their massive vertically integrated oil refinery, power plant, and naphtha cracker Liuqing, now located in Mailiao, Yunlin county.

Ultimately, the desires of the KMT industrial plans of the 70s and 80s sought to increase the mechanisms of value addition in Taiwan so that crude oil could be imported, refined into fuel oil, and concurrently serve as the material input that would filter down through other midsize businesses. The construction of the first, second, and third, and fourth CPC naphtha crackers were part of an effort to reduce the petrochemical industries' reliance on imported midstream materials for the manufacture of downstream plastics and fibers.[89] As Chen and Ku review, the shift from plastic products for the domestic market to an export oriented market for electronics and polyester textile fibers and yarns by the mid 80s stimulated immense upstream demands for acrylic-butadiene-styrene (ABS) plastics, pure terephthalic acid (PTA) and acrylonitrile (AN). By 1989, Taiwan was the second largest producer of synthetic fibers in the world, second only to the United States.[90] This is in addition to the wide variety of other plastic products that were serviced through this upstream expansion of a wide variety of petrochemical materials.

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[88] Chen, Tain-jy and Ying-Hua Ku "Second Stage Import Substitution" *The Political Economy of Taiwan's Development into the 21st Century*. Edward Elgar Publishing, 1999. 94

[89] Ibid, 95-7

[90] Ibid, 91

This era of development characterizes how the ubiquity of petromaterials and their use in the fabric of life had galvanized KMT and corporate interests toward expanding access to oil, despite geological and geopolitical restrictions on oil resources. US overseen development created an export economy based on the materiality of oil, and throughout the OPEC oil crisis of the 70s, the state and Formosa repeatedly sought to expand their materials business. Much of this was done through paradiplomatic means, as this period also coincided with the international derecognition of Taiwan as a formal nation-state.

1. Upstream Feedstocks and Global Oil Regimes

With limited access to oil reserves in Taiwan, regular oil shipments from Japan and the US served the dual purpose of providing both feedstocks for petrochemicals and jet fuel for Taiwan's new Sabrejets bestowed through US military aid. After the 1958 Taiwan Strait conflict, fighter jets became an essential part of the KMT military regime to fight off CCP bombing aircraft that targeted islands in the Taiwan Strait.[91] However, as Chiang Kai-shek and the KMT held on to the notion that they might somehow retake the mainland, they insisted on maintaining a large military, often at the expense of other aspects of the economy, made clear in through the "military burden" analyzed in the post-aid US commissioned Jacoby report.[92] After the KMT success in the Taiwan Strait Crisis, a joint communique signed by Secretary of State John Foster Dulles and Chiang in

[91]Lewis, Reese P. *The origins of Taiwan's trade and industrial policies*. Dissertation. Columbia University, 1993.137-9.

[92] Jacoby, Neil. H. "An Evaluation of U.S. Economic Aid to Free China, 1951 - 1965."; See Appendix, Disaster STS

October 1958 that assured the continuation of US aid and no reduction of military capacity, if the military existed for defensive purposes only.[93] The KMT military was by far the largest consumer of oil from the state-owned CPC and other refiners, consuming 65 percent of the total petroleum products in 1956.[94]

According to Cullather (1996), the maintenance of this fleet of Sabrejets and the assurance of US military aid relied on the income derived from an export oriented economy. To maintain the aircraft, the KMT had to import 5-6 million USD worth of fuel and parts each year, and while assisted by US aid, this amount primarily had to be earned through export-generated income.[95] The contingency of economic and military function on foreign aid gave the US what Gold (1984) calls a "de facto veto" over their actions, due to US control of the KMT's "economic lifeline," as well as their military supplier.[96] These authors, in one way or another, use this dependent relationship in military and economic aid as evidence against the predominant government narrative that emerged after the 'graduation' of Taiwan from US aid in 1965, that the development of the military dictatorship in the "Free China" was evidence for the successes of a free market. Though formal economic aid ended by 1965, select military aid from the US and US companies has continued up until the present day, in addition to the reliance on US adjacent technology and trade networks for the supply of oil and military defense technology. Further industrialization was necessary to maintain the KMT military, one of the largest per capita at the time.[97]

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[93] Cullather, "'Fuel for the Good Dragon'" 21
[94] Ibid, 19
[95] Ibid, 21-2
[96] Gold, *State and Society in the Taiwan Miracle*, 155
[97] Jacoby, "An Evaluation of U.S. Economic Aid to Free China 1951-1965" 35

This reliance on US aid and the volatility of the KMT in its control of access to state-owned portions of the economy, making unfavorable conditions for DFI. Oftentimes foreign firms were explicitly or implicitly excluded from joint-stock ownership of state-owned and private companies, and complete foreign ownership was prohibited outright, with special privileges given to US firms.[98] In the petrochemical sector, US companies were involved with joint ventures with the state-owned CPC, including a joint venture with US company National Distillers and Chemical Corporation to manufacture low-density polyethylene plastic in 1964. This plant led the CPC to commission its first naphtha cracker in 1965, which opened in 1968 to supply two-thirds of its production to the polyethylene plant. In 1966, the CPC forced the 4 largest PVC manufacturers to merge in a joint venture with CPC, in order to adopt a more efficient PVC manufacturing process and to utilize the excess ethylene produced by the future naphtha cracker. One-third of the naphtha cracker's production was earmarked for the new combined PVC plant.[99]

While the petrochemical sector remained largely under state organization, the conditions for DFI changed dramatically after the end of US aid in 1965. The KMT pursued aggressive export-oriented industrialization, including the development of Export Processing Zones (EPZ) to solicit DFI and generate rent for its massive military force. The Kaohsiung EPZ was the first to open in 1966, and included a modern harbor adjacent to an industrial park near where Formosa Plastics was located.[100] DFI from US and Japanese companies poured into the electronics, plastics,

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[98] Ibid, 23;

[99] Wade, Robert. *Governing the Market: Economic Theory and the Role of Government in East Asian Industrialization.* Princeton University Press, 1990. 91-2

[100] Gold, *State and Society in the Taiwan Miracle*, 177; Wang Yufeng 2018

and garments sector, with large US transnational corporations primarily setting up their electronics production for export to cut costs on goods for the US market.[101] Japanese firms instead sought out partnerships with local Taiwanese firms to undergo labor-intensive and technologically incomplex manufacturing, while reserving high value added goods for production in Japan.[102] The investment in these industries from Japan and US at this time denote the KMT's interest in establishing a petromaterial, export-oriented industrial corridor in Kaohsiung, as they still had intimate control over many aspects of the industry.

With the derecognition of Taiwan in 1971 by the UN, and the derecognition by Japan in 1972, Taiwan's currency had devalued and their trade deficit increased dramatically. By 1972, as Nixon had begun talks with China in the early stages of the One China policy, and with the subsequent 1973 OPEC oil price shocks, the necessity of securing oil feedstocks became an existential matter for the KMT government and economy. Yet, the KMT government pursued even stronger economic and industrial control over expanding the oil industry, implementing the Sixth Fourth-Year Plan from 1973-76 that supported further advances in petrochemicals, electronics, precision machinery, and computers, all primarily for export.[103] Though this plan was scrapped in favor of a Six-Year Plan from 1976-1981, it similarly established advances in petrochemicals and other capital-intensive industries, specifically with the intention of vertically integrating downstream textile and plastics production with upstream petrochemical production in

[101] Gold, *State and Society in the Taiwan Miracle*, 178
[102] Ibid, 179
[103] Ibid, 96

coordination with almost entirely US oil companies.[104] Government established industrial parks became standard response to oil price increases, such as the Hsinchu Science Park. The founding of the Industrial Technology Research Institute (ITRI) that incubated the early Taiwan Semiconductor Manufacturing Company (TSMC) also corresponded with the OPEC oil price increases of the 70s.[105]

The oil price shocks of the 1970s still put pressure on the supply of oil and naphtha to these newly founded industries, with Taiwan being dependent almost entirely on foreign oil. With the US derecognition underway, Taiwan turned to the Middle East in search of oil supplies for its export oriented economy, specifically Saudi Arabia. The KMT government sought to establish relationships with the Saudi Arabian government, sending government run construction firms overseas to construct a 110-kilometer long highway from Mecca to Hawiya in 1973.[106] This was followed by the construction of an industrial park and sewage system in Yanbu, the Shaar desert highway, offshore and onshore work at the Jeddah port for the Saudi Naval Expansion Program, construction of military housing, construction of one Riyadh's industrial state and airport, and the Jeddah-Mecca expressway.[107] The Taiwan Power Company had a diplomatic mission starting in 1975 to provide technical assistance and construction capacities to the Saudi Ministry of Industry and Electricity, which was provided at a financial loss in favor of government to government aid. In exchange for imported oil products, Taiwan exported a diverse array of textiles, electronics, and

[104] Ibid, 98, 221

[105] Ibid, 98

[106] Wang, T. Y. "Competing for Friendship: the Two Chinas and Saudi Arabia" *Arab Studies Quarterly* 15:3, 1993. 66.

[107] Ibid 66-7

building materials back to Saudi Arabia. The KMT government also refused to buy fighter jets from Israel, supporting the Saudi position on the Arab-Israeli conflict in favor of strong diplomatic ties.[108] Though Saudi Arabia developed a diplomatic relationship with Beijing in the late eighties, likely to secure missile and weapons text passed the US pro-Israel lobby and eventually switching its official recognition of the CCP, a diplomatic mission to Taipei assured the KMT government that supply of oil would continue at the same volume.[109] Even after this derecognition, Saudi Arabia was still the largest oil supplier to Taiwan and the state-run CPC, supplying 40 percent of its oil annually.[110] The construction of highways, industrial parks, and ports in Jeddah and Yanbu can also be seen as direct contracting aid to help facilitate export of oil.

The KMT also sought to secure state control over the flow of oil from Saudi Arabia, dissuading large sums of capital from accumulating outside of Taiwan. In the mid-seventies, the KMT government intervened in a deal between Y. C. Wang and the Saudi Arabian state, who wanted to establish FPC's own oil refining and supply facilities in the middle east to secure upstream access to resources. Instead, the CPC established an oil-refining and fertilizer plant in cooperation with the Saudis, insisting that a resource as strategic as petroleum and oil should be run by the state.[111] The control of the state in aspects of Taiwanese capital abroad allegedly caused investors to avoid the stock exchange during the KMT era, as the government had de facto control of the Securities and Exchange commission.[112] This initiative from the KMT is representative of their existential need to

[108] Ibid, 67
[109] Ibid, 74-5
[110] Ibid, 64
[111] Wade, *Governing the Market*, 129
[112] Ibid, 270-1

track down oil sources to provide fuel and feedstocks to an export economy almost entirely dependent on downstream processing of oil products.

Y.C. Wang poses for a picture with then president Ronald Reagan. Formosa Plastics Museum

2. Plastics Paradiplomacy

This mechanism of KMT upstream control for diplomatic purposes may allude to why FPG formed a US subsidiary company in 1978 and expanded into the US, buying derelict plastic processing facilities in Louisiana, Delaware, Illinois, and notably Point Comfort, Texas in 1981.[113] This process in scouting the locations of Point Comfort and Baton Rouge has been explored by

[113] Gold, *State and Society in the Taiwan Miracle*, 219

Tubilewicz (2022) as a paradiplomatic process in which subnational actors enacted business decisions within neoliberal economic order.[114] However, I would extend this diplomatic function to a global network in which Formosa, and to a lesser extent the Taiwan state, used private petrochemical capital to sustain economic and paradiplomatic relations in an ongoing period of international derecognition. With FPG's current planned project in St. James Parish, Louisiana, the Sunshine Project is a massive ethylene cracker assumedly proposed in response to the ample natural gas feedstocks of the US shale-gas boom. This strategy has served concurrent purposes of global diplomatic linkages and profitable access to upstream feedstocks.

As part of a concurrent trend of Taiwanese capital, FPG also expanded into China in the late 80s and early 90s. However, the data on the extent to which Taiwanese companies invested in production in China during this time is unclear, as nearly 60% of cross-straits trade was conducted through direct interaction during the period of economic liberalization in China and the democratization of Taiwan.[115] Formosa's relationship to Chinese production seems to be largely reliant on owned or joint venture corporations under the FPG conglomerate umbrella that produce various metal and plastic components from feedstocks. A map of Formosa facilities in the Formosa Plastic Museum listed eight facilities in China, including the large Formosa complex in Ningbo City, Zhejiang Province, a Nanya Printed Circuit Board facility in Jiangsu, and Formosa Taffeta fiber manufacturer in HongKong. The Ningbo plant seems to be particularly large and

[114]Tubilewicz, Czeslaw. "Foreign capital and US states' contested strategies of internationalisation: a constructivist analysis." *Contemporary Politics* 28, no. 4 (2022): 386-407.

[115]Mengin, Françoise. "Taiwanese politics and the Chinese market: Business's part in the formation of a state, or the border as a stake of negotiations." in *Politics in China: Moving Frontiers,* Palgrave Macmillan, (2002): 232-257.

similar to the configuration of Liuqing, in that metals, fibers, plastics, and bulk petrochemicals are produced concurrently with naphtha cracking.

In the context of a greater state struggle for access to upstream feedstocks, private petrochemical capital's spread into the US and China characterizes a petrochemical growth that emerged in part through state and private efforts to secure oil resources. Yet, within the production of the company itself, this period of capital investment is also a moment of technological upgrading and diversification within FPG's petrochemical production. This period saw the expansion of downstream facilities in both China and the US, while upstream feedstock production was expanded in Taiwan until reaching significant opposition from communities and environmentalists. As Taiwan's fledgling democratic government grappled with an emerging environmental movement and a legacy of authoritarian industrialization, the 2000s marked a shift towards domestic vertically integrated petrochemical plants, with the establishment of Liuqing and the attempted development of the state operated Kuokuang petrochemical complex.

D. Petrochemical Resistance and Vertical Integration 1987-Present

This process of industrialization was not without consequence for communities that had to deal with the immense burden of petrochemical production within their towns, particularly vocalized after the end of KMT martial law. Ho (2014) details this process of resistance to petrochemical development as part of a sociopolitical shift and watershed moment of Taiwanese environmental movement in 1987. As vocalizing political opposition was made possible through democratization, new petrochemical projects became focus points for resistance to environmental degradation and the KMT government. The first protest movement against a new naphtha cracker was just two months after the government announced the end of martial law, in July 1987.[116] However, these protests were inspired in part by the successes of the "Lukang Rebellion" in which a community of fishermen successfully prevented the construction of a DuPont titanium dioxide plant in Changhua County in 1986. These sentiments galvanized the emergence of the Democratic Progressive Party (DPP) as a challenge to the authoritarian rule of the newly democratized KMT political party.[117] By August of 1987, the Taiwan Environmental Protection Administration (EPA) was formed by the KMT, but the technocratic approach to regulation damaged the public credibility of their environmental impact assessments for years to come.

Following the end of martial law but still under KMT governance, protests against construction of the CPC's fifth naphtha cracker in Kaohsiung and FPG's Liuqing in Mailiao. As the DPP entered power under the presidency of Chen Shuibian in 2000, they favored business-forward policies despite their initial alignment with the environmental movement. This period saw the support of continued petrochemical expansion, such as the upgrading of the third naphtha cracker, and spurred grassroots movements that halted plans to construct the seventh and eight naphtha crackers and the Kuokuang petrochemical project.[118] Liuqing's location was also

[116] Ho, Ming-sho. "Resisting Naphtha Crackers: A historical survey of environmental politics in Taiwan." *China Perspectives*, no. 3 (2014): 5-14. 6

[117]Jobin, Paul. "Hazards and protest in the "Green Silicon Island". The struggle for visibility of industrial hazards in contemporary Taiwan." *China Perspectives* 2010, no. 2010/3 (2010). 46-8

[118]Ho, "Resisting Naphtha Crackers," 7.

disputed by several civilian protests in Yilan and Taoyuan counties until finally ending up in its current location in Mailiao, Yunlin, in part due to efforts from the central government to secure their investment over fears that Formosa would shift the project to China.[119] The massive petrochemical complex Liuqing began operation in 1999, securing FPG's access to its private upstream source of feedstocks it had desired since 1973.

FPG's initial investment in Liuqing totaled over 17 billion USD (574 billion NTD), and at the time of construction was the first fully integrated complex of its kind. It could refine crude oil, process it into propylene and ethylene, and crack and further refine these feedstocks into a wide array of downstream chemicals, and by 2008 was generating over 30 billion USD in annual output value. It specialized in producing intermediate and downstream materials such as vinyl chloride monomer (VCM), PTA, PVC, styrene monomer, acrylic esters, ethylene glycol, and epoxy resin.[120] FPG subsidiary Nanya benefitted from sources key materials such as ethylene glycol, both for inhouse use and export, particularly as supplies of the chemical were constrained following an explosion at a SABIC ethylene glycol plant in 2007.[121] This particular moment saw Formosa's profits in midstream and downstream chemicals skyrocket, leading FPG to surpass CPC as the largest petrochemical producer in Taiwan and become one of the top ten petrochemical producers of the coming decade.

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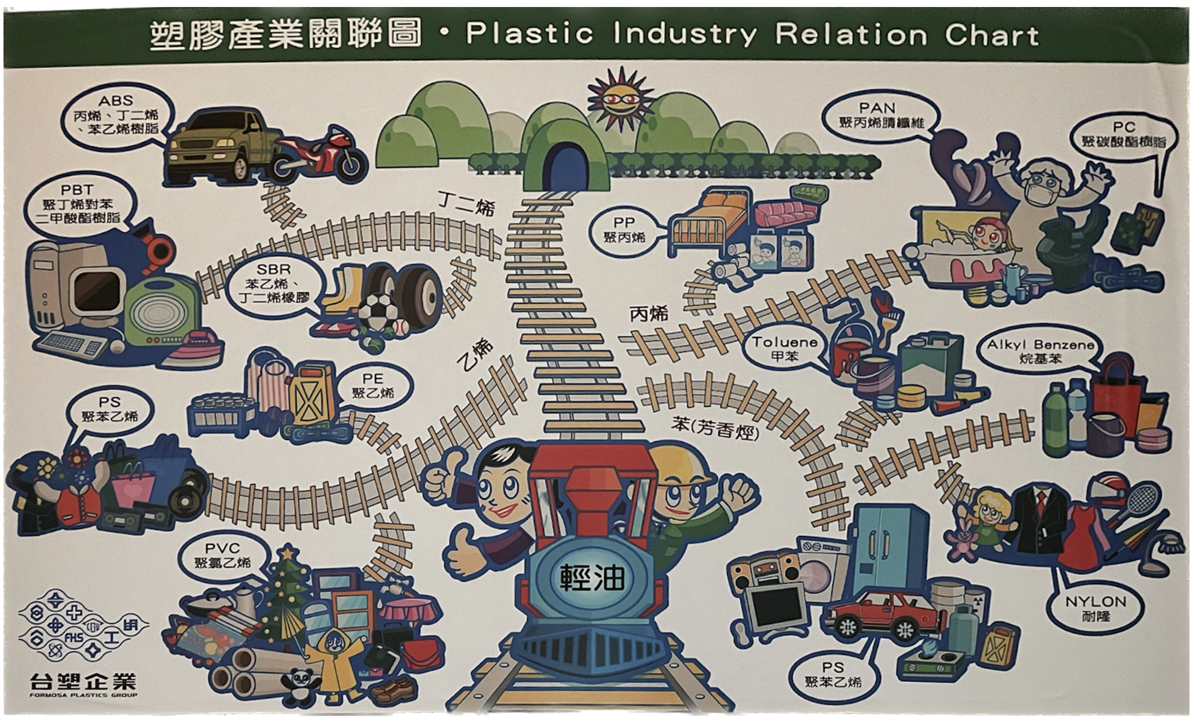
[119] Ibid, 8.

[120] Huang, Ching-Hsuan (2008) "Formosa Plastics Group: Wang Yongqing's Living Legacy" *Commonwealth*, Vol. 392.

[121] Huang, Ching-Hsuan (2008) "Nanya Plastics Corporation A Twin-engine Revolution" *Commonwealth*, Vol. 392.

III. Plastic-in-use: Petromaterial Ubiquity and Technology

"Humanity is about to face the dilemma of oil depletion, and electric vehicles are the best solution to the energy crisis. As long as we can master the manufacturing of electric vehicle batteries and cooperate with low-cost production conditions and management, the future is optimistic." - Y.C. Wang 1998, founder of Formosa Plastics[122]



Plastic Industry Relation Chart, from the Formosa Plastics Museum in Taoyuan, Taiwan. The center of the steam engine in the lower middle section of the graphic says 'Qingyou' or naphtha, a byproduct of the refining process used as the input in making plastics.

It may seem trite to say that wind turbines, electric vehicles, and solar panels contain plastic parts. Everything contains plastic parts, so why dwell on something as crucial as renewable energy technology when plastic is so ubiquitous? It is precisely this ubiquity that makes the usage of petrochemical products so difficult to interrogate. As Adam Hanieh writes, "petrochemicals are the means through which oil has become woven into the very fabric of our social existence, yet this

[122] Formosa Smart Energy Company "About us," See Appendix, Disaster STS; This quote is also visible in the Green Energy display of the Formosa Plastics Museum

ubiquity has made them almost invisible to our everyday consciousness."[123] In his review of the origins of the petrochemical industry, he goes on to discuss how this centering of 'chemicalization' of industry led to "all forms of commodity production linked to petrochemicals in some manner."[124] In part, it is this ubiquity that also allows technology and the petromaterials assumed in its design and implementation to exist abstracted from its material origins. The 'imaginaries' that create techno-solutions to the crisis of carbon emissions from fossil fuels are materially constrained by the limited design realities of petromaterials, yet removed from their natural origins of oil.

The purpose of this chapter is to employ a political-industrial ecology perspective to understand how plastic, or petromaterials in general, are implicated in the design criteria and material production of the energy transition. By viewing petromaterial production within a greater industrial supply chain, I aim to question how the energy transition is framed as an end to material uses of oil, and thus a challenge to its hegemonic power, through locating the production of renewable energy technologies within a greater context of petrochemical production. These linkages aim to help environmentalists interrogate how these technologies are connected materially and socially to the very same oil worlds that allowed for the mechanism of statecraft and control of regimes such as the KMT.

Many of the fossil companies that obstruct diversions from business-as-usual strategies are relying on unmitigated emissions, but their profits largely come from the ways that their products, as fuel and material, are used downstream in modern Fordist society as arranged by state function.

[123] Hanieh, "Petrochemical Empire" 28
[124] Ibid 18

Fossil fuels have been the source of energy, and the usage of fossil fuels has been assumed in the infrastructure and institutions that are produced and reinforced by the state. The role of the state has historically been to provide energy as an essential function of economic growth and the development of modernity, but the way it entrenches resource demand is determined more so by the necessities of capital accumulation. As Newell and Paterson (1998) discerned from global inaction over carbon regulations, the interests of the state as reproducers of capital often supersedes their interests as rational actors in collective regulation.[125] As states globally seek to provide alternative sources of energy to mitigate business-as-usual scenarios of carbon emissions, the way that "specific capital" interests are incorporated in this development of accumulation of capital-in-general is determined by the demands for resources.[126] For the development of energy technology, this material is provided by industries within and through oil and gas production, and in countries where export-oriented technology production are historically entrenched in economic and state function, this use of petromaterial is entrenched in downstream applications in a similar manner as use of fossil fuels.

This nexus of converting oil and gas to useful materials, such as plastics, is the basis for the petrochemical industry's 'business-as-usual.' However, the term's definition as the typical operations of an industry includes the relatively heterogeneous behavior of aspects of the global fossil industry in creating materials for a wide variety of downstream applications. In places where technology is manufactured, this 'specific capital' of petrochemical interest within the material

[125]Newell, Peter, and Matthew Paterson. "A climate for business: global warming, the state and capital." *Review of International Political Economy* 5, no. 4 (1998): 679-703.

[126] Ibid, 692

conditions for production of technology is coordinated by the state to further accumulation of capital-in-general, yielding a wide variety of materials that make the base chemicals of technological production. Thus the manufacture of renewable technology in itself is not a direct challenge to capital-in-general, as the business-as-usual strategies of the petrochemical industry have historically reflected the use of specific fossil materials that are compatible with production of technology, within a state coordinating accumulation for development. In other words, climate change mitigation pathways characterized as sustainable development incentivize a specific use of oil and gas capital, as opposed to an outright challenge to its configuration.

As Alice Mah (2023) has discussed, the petrochemical industry can often skirt responsibility for its contribution to global toxicity by showcasing its "monopoly on the technical expertise needed for providing many green technological 'solutions.'"[127] Formosa Plastics Group is emblematic of this, as many of the conglomerate's sustainability reports, museum displays, and public exhibitions are plastered with images of wind turbines and showcase the specs of their solar cells and battery storage solutions. Superficially this appears to climate critics as mere greenwashing, and while this imagery distracts from the relatively small proportion of profit generated from renewable energy technology when compared to other plastic products, there is a reality within this corporate messaging that cannot be ignored. The petrochemical industry often provides the only suitable material available to make renewable technology not just feasible, but

[127] Mah, *Petrochemical Planet*, 121

possible. Without large scale production of cheap, technically specific, and yet ubiquitous plastic, what are these things to be made from?

This case study of Formosa's recent ventures into renewable energy demonstrates how historical constraints on fossil fuels have incentivized Taiwan and the petrochemical industry to pursue applications of petromaterials in adjacent industries, as a business strategy that prioritizes oil's material use. These strategies exist in a context of petrochemical coordination toward technology production in Taiwan, and greater anxieties about the future of oil as the main fuel and material source. This phenomenon interrogates what exactly 'business-as-usual' is for the petrochemical industry, and whether or not renewable energy technologies truly disrupt the 'usual' function of oil capital.

This chapter focuses on three key technologies to understand petromaterial's downstream applications. First, I overview petrochemical production to show how petromaterials are generated alongside fossil fuels. Next, I look at how the petromaterial inputs were coordinated by the state amidst the energy crisis, to serve as high value inputs in the manufacture of semiconductors and microelectronics for export, and the ways that supplies of specific cleaning chemicals and tools are crucial in this process. I Then look to how Formosa's ventures into experimental electric vehicles in the 90s was in part a response to the looming perceived crisis of peak oil, the research of which served as the early foundation of Formosa Lithium Oxide Company in materials sourcing and Formosa Smart energy's emerging role in battery manufacturing. Lastly, I look into acrylonitrile feedstocks and carbon fiber production under Formosa's monopoly on carbon fiber production in

Taiwan, and the implication of this for the wide scale implementation of offshore wind farms, as part of the Taiwan government's goals for energy decarbonization.

A. Oil goes in, Fuel *and* Materials Come Out

Many often conflate the end of fossil fuels with the end of oil and gas. Currently, countries such as the US and China are making greater industrial commitments to producing electric vehicles, solar panels, wind turbines, and developing artificial intelligence and carbon capture technology to begin to counteract carbon emissions globally. At the same time, new natural gas based plastic plants are being constructed to make increasingly more plastics. While decarbonization may decrease the amount of fossil fuels that are combusted at the industrial and consumer scales, the process of refining oil yields a variety of other materials for technological development and economic opportunity. The petrochemical industry, through the processing of byproducts from the refining of fossil fuels, creates technically specific chemicals that are applied downstream to help create technologies, including decarbonization technologies.

Technical production in the petrochemical industry can largely be defined as a managed system of series of chemical reactions that produces both fossil fuels and petromaterials. At Liuqing, and most other large scale naphtha crackers, the first stage is fuel oil refining, which begins by distilling crude oil into lighter densities called fractions. Depending on the composition of the crude oil, the refinery yield can contain a combination of fuel oils, including diesel and kerosene jet fuel. This process also yields heavy and light naphthas as byproducts. Ironically, this process of refining is often referred to as "organic" production, as opposed to "synthetic" production where materials are not refined, but synthesized from chemical reactants.

Petrochemical industry strategies typically have focused on the further processing of byproducts from the refining process. Depending on the length of the carbon chains in the naphtha, different end uses are possible. Light naphtha is often 'cracked,' where the carbon chains are broken down into shorter configurations through exposure to intense heat and pressure, creating ethylene and propylene chemicals which become the inputs for most plastics, which are typically chains of ethylene or propylene monomers that become polyethylene and polypropylene polymers.[128] Light naphtha is occasionally used as fuel in the form of butane or kerosene, or is mixed in small quantities into heavy naphtha as a method of fuel blending, but the majority is turned into plastic products. Heavy naphtha undergoes catalytic reformation, a process which makes it applicable in high octane gasoline and creates other long hydrocarbon chain materials such as benzene, toluene, and xylene (BTX). Each stage of reaction uses inputs from previous stages of oil refining to create different materials, yielding specific chemicals with specific properties. These stages of reactions also yield further byproducts, which can either be stored, reused at earlier stages of processing to add unique qualities to other plastic materials, or released into the greater environment as emissions.

This array of chemicals products (including more not listed) provide material qualities of plastic that fit specific design requirements for new technologies. Some of the older examples of

[128]IEA, "The Future of Petrochemicals," 19

technology created from these products and byproducts include synthetic rubber, which grew to replace natural rubber grown on plantations. By the 1950s, US engineer's use of naphtha byproducts became a strategy of adding value to oil refining, from which plastics and other chemicals could be used in other downstream industrial applications. This model was exported to many post-WWII countries as a developmental strategy, and is the origins of the petrochemical industry in Taiwan, as chapter 1 explores. Now instrumental in producing everything from fast fashion to precision aerospace parts, plastics are figuratively and literally embedded in the function of modern society.

The entrepreneurial logic that governs the petrochemical system of production is that each of these byproducts can be utilized to add value by synthesis of a new chemical product or a novel application of an existing one. For example, hydrogen gas is emitted as a byproduct at many stages of refining, and is often captured and used as an input to make synthetic fertilizers. However, when a chemical is not operable at a different stage of production or able to be conveniently stored, it is emitted out of the system. This can be said for carbon dioxide, methane, nitrous oxide, carbon monoxide, nitrogen dioxide, particulate matter (PM10 and PM2.5), and sulfur dioxide, emitted during both the chemical production and process and through the combustion of fuels for energy. Material products such as olefins are often categorized as volatile organic compounds (VOCs), and can be emitted from this system through chemical off-gassing of stagnant chemicls.[129] Other chemicals can be emitted in the form of leaks, accidents and explosions, or intentional releases,

[129] Young, Ben, Troy R. Hawkins, Caitlin Chiquelin, Pingping Sun, Ulises R. Gracida-Alvarez, and Amgad Elgowainy. "Environmental life cycle assessment of olefins and by-product hydrogen from steam cracking of natural gas liquids, naphtha, and gas oil." *Journal of Cleaner Production* 359 (2022): 131884.

including finished products such as the plastic particulates or as post-consumer waste. Like carbon emission, deferring responsibility for this type of leakage is necessary for this system to function and maintain its profitability, by putting the burden of managing its waste onto the greater environment.

As Tickner et al. (2021) have noted, the production of basic feedstock chemicals is more suited to larger petrochemical suppliers and must operate at scale to maintain profitability.[130] Take the components of carbon fiber and epoxy resins that make up wind turbine blades as an example: naphtha is produced as the byproduct of fuel oil refining in large quantities, after which it is steam cracked into propylene, becoming the feedstock that later becomes acrylonitrile, then polyacrylonitrile, from which it can be spun into fibers and oxidized into carbon fiber, with some additive chemicals to create specific qualities of the fiber. Epoxy resins, or specifically BPA vinyl esters are the products of multiple streams of production, including methyl alcohol from natural gas, vinyl acetate from propylene or ethylene production, and benzene, toluene, and xylene (BTX) isomer aromatics sourced from chemicals collected from catalytic reforming of waste products of naphtha refining.[131] In other words, the specific characteristics and production of these materials is dependent on both large scale production, and the production of countless other chemicals that are created as byproducts of other reactions. The technical specifications necessary for durable and lightweight wind turbine blades are thus created only through large scale production, where

[130]Tickner, Joel, Ken Geiser, and Stephanie Baima. "Transitioning the chemical industry: the case for addressing the climate, toxics, and plastics crises." *Environment: Science and Policy for Sustainable Development* 63, no. 6 (2021): 4-15.

[131]Levi, P. G., & Cullen, J. M. (2018). Mapping global flows of chemicals: from fossil fuel feedstocks to chemical products. *Environmental science & technology*, *52*(4), 1725-1734.

countless other products of other chemical reactions are also produced at the same site to create the specific chemical compositions and technical properties of the materials necessary for its function.

Mah (2023) recounts a concept about the inability for petrochemicals to be produced without also producing byproducts as a result of the reaction. She mentions this as the "'two-for-one principle'" in which "less-toxic petrochemicals cannot be produced in isolation from the more-toxic ones" as "that chemical processes involve generating by-products, all of which need to find places to go, whether into new processes and products, or into waste disposal."[132] The generation of technically specific chemicals is similarly reliant on chains of reactions upstream, with the usable ingredients of any specific chemical formula coming from waste byproducts that are being used into other products. Each of these reactions transforms matter into substances with varying degrees of toxicity, and petrochemical manufacturers must then decide what happens to each of these products of each reaction, whether they be released into the greater environment, or stored in a tank and maintained until it can finally be moved and reused into other products. For a material to succeed as a profitable substance, it is thus dependent on all of the chemical reactions that precede it, either as an input into its manufacture or expelled as waste. In this way, petromaterial products in general are all dependent on one another for their own chemical composition and economic viability, reliant within an intricate system of reactions. Each product at each reaction stage must either be emitted into the air or water, stored onsite, or further processed into other plastic products, each with different scales of risk and toxicity. So for the

[132] Mah, *Petrochemical Planet*, 104.

specific, technical properties of many modern technologies that utilize petromaterials, these products are reliant on large scale upstream production that creates toxicity as an inherent logic.

B. Oil Crises and Downstream Value Addition

This section examines how Formosa Plastics, and Taiwan in general, pursued applications of petromaterials as a developmental strategy amidst anxieties over a dwindling supply of oil. FPG's Nanya Plastics shifted from solely a plastics product manufacturer to include semiconductor and electronics manufacturing, as the KMT's industrial policy emphasized expansion of the material uses of oil. While this created an institutional and research support that incubated the early stages of Taiwan's semiconductor industry, it also created a pathway for oil to be used beyond its primary use as a fuel source, with many companies specializing in specific chemicals for their material applications. This legacy of material coordination has led to a petrochemical industry that is focused on petromaterial value addition as its primary business strategy. This context now provides the material qualifications for oil in the energy transition period, where its material use value and its technically specific design qualities create conditions for technological innovation to occur.

1. Semiconductors and Electronics

The vast majority of the world's semiconductors are produced by TSMC at foundries in Taiwan. As of the close of the fourth quarter of 2023, TSMC held 61.2 percent market share of semiconductor production.[133] This bottleneck of global semiconductor production is sometimes referred to as the 'silicon shield,' in which the importance of this highly specialized sector of technology production has protected Taiwan from military invasion.

Taiwan's rise to become the world supplier of semiconductor and microelectronics reflects the KMT's industrial policy combatting restrictions on oil access. In response to the OPEC oil crisis in 1973, the KMT founded ITRI to coordinate and technically upgrade existing industries to supply emerging demand for microelectronics. ITRI incubated early microelectronics and semiconductor companies through the early stages of their founding and is largely responsible for their success as private companies today. This shift was highly reliant on transnational Taiwanese who had been living and were educated in the United States, helping to create the vision for a Taiwan Silicon Valley in Hsinchu industrial park.[134] These individuals advised the KMT to pursue a development strategy that focused on high-value technological development, in contrast to the relatively Fordist postwar development of Korea and Japan.[135] In Taiwan, through government coordination via organizations like ITRI, a materially focused pattern of development entrenched petromaterial use in a way reminiscent of Fordism and fossil fuels. This developmental coordination between upstream industries and semiconductors is clear in the founding composition of TSMC as a joint venture between the KMT state government, Philips, and Taiwanese petrochemical companies,

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[133] Herh, Michael. (2024) "TSMC's Foundry Market Share Crosses 60%, Further Widening its lead over Samsung Electronics" *Business Korea*.

[134] Guiheux, Gilles "Enterprises, Entrepreneurs, and Social Networks in Taiwan" in *Politics in China: Moving Frontiers*, Palgrave Macmillan, 2002. 204-5

[135] Feigenbaum, Evan A. "Historical Context of Taiwan's Technological Success" Assuring Taiwan's Innovation Future. *Carnegie Endowment for International Peace*, 2020. 6; see Saxenian Report

with companies such as Formosa Plastics and Sino-American Petroleum holding 5% and 4% shares respectively.[136]

In addition to expert transnational labor, the materials industry formed the basis of the development of high-tech manufacturing in Taiwan. Otto C.C. Lin, who formerly oversaw the Materials Research Laboratories (MRL) as established by ITRI, and later served as the director of ITRI from 1988-1994 after Morris Chang became CEO of TSMC, wrote that "the beginning of the high-tech industry in Taiwan can be traced back to the 1970s" as part of the Ten National Construction Projects under the KMT.[137] Lin writes that the "naphtha-cracking plants of CPC, along with CPDC's [China Petrochemicals Development Corporation] acrylonitrile and terephthalic acid plants, have supported Taiwan's petrochemical, plastic and synthetic fiber industries. The polymers produced by enterprises such as FPG, China General, and Chi Mei are highly regarded in the world market."[138] Here, Lin shows that while the manufacturing of microelectronics was enabled by a variety of elements including access to technology, proprietary knowledge, and human resources, the industry was additionally enabled by the large-scale manufacturing of specific types of plastic for the world market. From these chemical and material feedstocks, the incubation of the early chip industry was possible through access to a plethora of chemical building blocks for the necessary materials.

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[136] Mengin, Francois. *Fragments of an Unfinished War : Taiwanese Entrepreneurs and the Partition of China*. Oxford University Press, 2015. 87; See Hong 1995

[137] Lin, Otto C.C. "Science and technology Policy and its influence on economic development in Taiwan" *Behind East Asian Growth: the political and social foundations of prosperity*. edited by Henry S Rowan. Routledge, 1998. 196

[138] Ibid 196

Finding the specific niches of global chemical demand was part of a planned strategy of central government organizing. In the 1981-1989 Ten-Year Petrochemical Industrial Plan for Taiwan, the government began to consider pursuing a strategy to pursue "quality" over "quantity" in petrochemical production. They cite constraints on imported oil supply as stimulating a shift to technology intensive production that focuses on "high-performance plastics" and "specialty chemicals" for downstream technology production. "Obviously, our petrochemical industry is almost fully grown with respect to "quantity", and our future efforts should be directed toward quality upgrading, technology independence, and high value-added products. Since we depend almost totally on imports for our crude oil, costs of basic materials are bound to be higher than in feed-stock countries. In order to overcome these disadvantages, we should shift to a technology intensive orientation, developing key intermediates, high-performance plastics, and specialty chemicals..."[139]

Direct access to this materiality enabled the development of a wide variety of petrochemical ventures in electronics manufacturing in Taiwan. In 1983, FPG subsidiary Nayna Plastics first began to experiment with directly manufacturing integrated circuit boards under the direction of Y.C. Wang's son Winston Wang. As part of their vertical integration strategy, Nanya's early production utilized materials sourcing necessary for microelectronic production to cut costs, including copper clad laminates, epoxy resins, and fiberglass cloth. Since then, Nanya has taken

[139] IFC. "Ten-Year Petrochemical Industry Development Plan for Taiwan, Republic of China (1980-1990)" *Industry of Free China*, 1981; via Lauridsen, "Policies and institutions of industrial deepening and upgrading in Taiwan I"

steps to begin developing actual components of integrated circuits themselves, manufacturing silicon wafers and DRAM integrated circuits.[140]

During this time, Nanya shifted from a general plastics producer to majority of revenue being generated by the value addition of electronics. By 2007, only 10 percent of its revenues came from plastics, whereas 42.4 percent was generated through sales of electronic products and 28 percent of petrochemicals.[141] Value added electronics products and niche petrochemicals generated substantially more revenue than raw plastics, but were produced in tandem and at scale with products used in both electronic manufacturing and other applications, such as ethylene glycol used in polyester textiles and Bisphenol A (BPA) used in epoxy resins. In a 2007 expose on Nanya in *Commonwealth Magazine,* in 2007 an industry analysis said that "'Formosa Plastics Group's practice has been to integrate vertically upstream. With plastics and chemicals at the root of most materials used in the electronics sector, upstream petrochemicals have been the strategic foundation for the group's diversified development."[142]

This phenomenon is reflective of other private petrochemical companies that specialize in manufacturing high value chemicals for applications in the manufacture of semiconductors and other electronic components. Changchun is a non-publicly traded petrochemical conglomerate that operates in central Taiwan, and has specialized in high purity chemicals for supply semiconductor manufacturing. "Chang Chun is the world's largest single supplier of several electronic device chemicals such as high-purity hydrogen peroxide, used to clean semiconductor

140 Huang, "Nanya Plastics Corporation A Twin-engine Revolution"
141 Ibid
142 Ibid

wafers from organic and metal residues, epoxy resin for the encapsulation of integrated circuits, as well as copper-clad laminates, which are key materials for making printed circuit boards. "When Chang Chun halts production for one day, the normal operation of Taiwan's electronics industry is thrown in jeopardy," reveals the former Taiwan-area president of an international petrochemicals company."[143]

The shift towards high value products is a trend that the industry in general is deliberating on in the energy transition period. Recent research shows that petrochemical manufacturers are pursuing strategies of high value chemicals and technologies amidst calls from the Taiwanese government to develop "circular economy" and "net zero" strategies.[144] The legacy of these developments now create incentives for new investment in microelectronics development within petromaterial producers.

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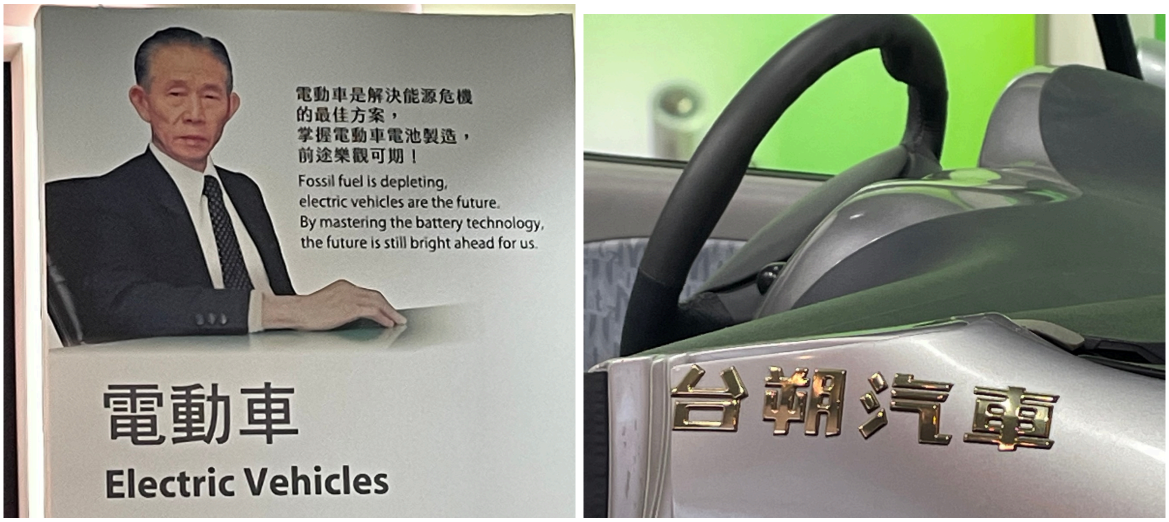
[143] Hsiung, Jimmy (2013) "The Edison of Petrochemicals" *Commonwealth*, Vol. 528.

[144] Jobin, Paul, and Erich Hellmer. "Taiwan Plastics Industry Toward 'Net Zero,'" paper presented at *The 20th EATS Annual conference*, SOAS, University of London: European Association of Taiwan Studies (EATS), 2023.

2. Electric Vehicles and Battery Storage Manufacturing



*The quote at the beginning of this chapter is attributed to Y.C. Wang, though its origins are unclear. A slightly different version of this quote is displayed at the Formosa Plastic Museum, stating that "electric vehicles are the best plan for solving the energy crisis," alongside an experimental electric vehicle developed by Formosa Automobile Corporation (*台塑汽車*). Photos by Author*

After nearly two decades of dealmaking acquiring derelict PVC plants across the United States, Wang concurrently turned his attention towards automotive manufacturing. Founded in 1996, Formosa Auto made early steps in manufacturing vehicles in Taiwan when Y.C Wang's former son-in-law Li Zongchang advocated for the company to purchase Sanfu Automobile. Li Zongchang had been educated in the US and had worked within Formosa to construct the Liuqing naphtha cracker before venturing into car manufacturing.[145] Formosa Automotive produced its first car, Formosa Auto 1 in 1999, through contracting with Korean Daewoo automotive and using an engine imported from General Motors.

[145] Lu, Guozhen "Formosa Plastics's Prince Consort is Out of Control" *Business Weekly* Issue 1055.

Influenced by reports on hybrid vehicle efficacy from Japan's Yano Economic Research Institute in 1997, Formosa Auto made steps to research battery technology for hybrid vehicles. The company wanted to manufacture hybrid and full electric vehicles at the Dadu and Wangtian plant in the Taichung port, and was sourcing nickel and lithium ion batteries from American battery companies.[146] This was around the same time as General Motors' early initiatives in developing electric vehicles in the US, which started manufacturing the GM EV1 in 1996 and ceased only 4 years later, drawing criticism from US environmentalists as oil-industry generated sabotage. While Formosa Automotive hoped to expand operations to the Taoyuan Science and Technology park, the company ultimately stalled by the mid 2000s, focussing instead on distributing DAF heavy transport trucks through subsidiary Formosa Freight.[147] However, the lithium battery materials research was retained and continued through subsidiary Formosa Lithium Iron Oxide Company.[148]

The quote at the beginning of this chapter has been invoked several times in the foundation of Formosa Smart Energy, a subsidiary run by Ruiyu Wang, purportedly to be fulfilling her father's "dream" by finally expanding Formosa's interests in developing battery technology. In 2022, Formosa Smart Energy announced the construction of the largest 5 GWh battery cell plant in Taiwan, investing in 16 billion NTD (approximately 500 million USD) to create a cornerstone of a domestic battery industry.[149] Formosa intends to manufacture these batteries with lithium material

[146] Formosa Plastics Group, "Introduction to Formosa Automobile Corporation," See Appendix, Disaster STS

[147]Shen, Mei-hsing "Broken dream! Taisu Auto blow out their lights" *Business Times*, November 22, 2007.;
Yao, Huizhen "Formosa Plastics, the leader to 2016, introduces heavy trucks from the Netherlands" *Apple Daily*, November 21, 2013.

[148] Formosa Plastics Group, "Formosa Lithium Oxide Company", See Appendix, Disaster STS.

[149] "Formosa Smart Energy Breaks Ground for Plant" *Taipei Times*, April 17, 2023.

reuse in mind, with advertised battery recycling rates as high as 90 percent.[150] The factory will produce battery cells that can be used in sequence for large scale energy storage. This system of battery storage from Formosa Smart Energy was debuted alongside Nanya Photonics, who advertised their ongoing projects as a designer and installer of solar photovoltaic (PV) systems. Nanya Photonics contracts to implement solar powered LED lighting systems, and aims to expand their production of PV panels to operate in conjunction with these integrated battery systems.[151] The company has also entered a tentative agreement with experimental electric vehicle manufacturer Aptera to supply lithium batteries for their vehicles.[152]A sample 1.3 MWh energy storage system, housed in a brightly painted storage container, was constructed at Formosa Biomedical Technology Corporation's Changhua plant and museum as a demonstrative installation of their battery technology.[153]

[150] Field Notes, October 18, 2023. Energy Taiwan.

[151] Formosa Plastics Group, "Nanya Photonics Flyer,"See Appendix, Disaster STS; Field Notes October 18, 2023. Energy Taiwan Conference

[152] "Going Solar" *Taipei Times* September 3, 2022

[153] Formosa Plastics Group, "Formosa Smart Tech Company Energy Storage Solutions" 3, see Appendix, Disaster STS

Batteries and storage system on display as part of Energy Taiwan 2023. Photos by Author taken Oct 18 2023

This plant is located in the Changhua Coastal Industrial Park (Changbin), a site that has been promoted by the Taiwanese government as the location of many new energy industries, particularly for wind energy.[154] Originally, the Executive Yuan selected the Changhua coast for the park as early as 1978, but was delayed until construction began in 1993. This delay, as well as the initial interest of Formosa in electric vehicles is attributed to the OPEC oil crisis of the 70s, in which access to oil reserves in the Middle East constrained economic growth for the petrochemical and other downstream industries in Taiwan. Similarly to the case of semiconductors, ITRI has been in part responsible for the development of various sustainable industries in the Changbin industrial park,

[154] Chen, Yajie "Changbin is booming: A new green energy technology settlement! Taiwan's largest industrial zones has gone from being in the limelight to being in the spotlight" *Wealth Magazine*, May 15, 2023.

coordinating companies to develop interconnected linkages and infrastructure through their "Forward-looking Infrastructure Demonstration Program."[155]

While much of this technology advertised is still being developed by these subsidiaries, their business models reflect a certain compatibility between non-fossil energy sources and the greater petrochemical material conglomerate. These subsidiaries see a business reality where integrated battery storage systems can take advantage of value-addition to petromaterials to cut costs and create the design possibilities of the ecological imaginary of the government's green initiatives. In the case of automobiles, this model was highly popularized through Fordist development, where centralized chemical companies could supply materials for components throughout car interiors, especially ABS plastic and synthetic textiles for the dashboard and interiors.

C. Fibers to Carbon Fibers, Carbon Fibers to Wind Turbines

The development of modern wind turbines depends on upstream access to a wide variety of petrochemical products, namely carbon fibers and epoxy resins. These chemicals have historically been derived from propylene and ethylene feedstocks, and fiber technologies emerged in Taiwan as part of synthetic textiles industrialization strategy. In the 1970s, Taiwan was a major exporter of textiles, utilizing initial import substitution and later reverse integration of upstream petrochemical feedstocks to lower costs for textile manufacture. This early export economy became

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[155] Ministry of Economic Affairs, " Department of Industrial Technology - Performance evaluation of the Innovation Foresight Project," See Appendix, Disaster STS

an important source of fiber technology, and developed industrial processes to produce necessary precursor chemicals, such as esters and acrylonitrile.

These petrochemicals served as an essential feedstock in the later development of carbon fiber technologies and epoxy resins. Carbon fiber is produced through the polymerization, spinning, oxidation, and carbonization of acrylonitrile.The combination of lightweight woven carbon fiber threads that can be formfit and shaped, combined with an epoxy that can soak into the material and creates a durable, firm, and watertight exterior create a material with immense industrial use. These materials, known as fiber reinforced plastics or generally as thermosets, are increasingly useful as a lightweight substitute for metal in many mobile technologies. Early applications of carbon fiber reinforced materials in bicycle frames were explored in the MRL under ITRI. Thus epoxies and carbon fibers have made up the basis for many transportation technologies manufactured in Taiwan, such as commercial airplanes, yachts and other watercraft, automotive parts. More recently, these materials have been useful in extending the longevity of wind turbines by reducing weight and increasing durability of the turbine blades.

In 2016 during the construction of Taiwan's first offshore wind energy field, developer Macquarie Group signed a memorandum of understanding between the Changhua County Government and a company called Swancor Renewable Energy to manufacture and install wind turbines off the coast of Miaoli County. The offshore wind project is the first of dozens of offshore wind farms set to be developed in the coming decades, most of which are owned and installed by European energy and appliance companies such as Siemens, Orsted (formerly Danish Oil and

Natural Gas), and Vestas. Since then, Swancor has specialized to produce a specialty blends of resins used in the manufacture of wind turbine blades produced in Taiwan, including as a key thermosets supplier for Vestas's wind turbines supply chain.[156]

Formosa Plastics Group is the only manufacturer of carbon fiber in Taiwan, and one of the largest globally. Formosa Chemicals and Fiber, which has historically been under the direction of Y.C. Wang's brother Y.T. Wang, has ample access to textile feedstocks that now serve as the material input for carbon fiber. In 2018, Swancor signed a memorandum of understanding with Formosa Heavy Industries and Formosa Plastic Corporation to supply material necessary for wind turbine construction.[157] This includes carbon fiber for longer and lighter blades, but also for gearbox components, as well as steel for the structures of the turbine stands and subsurface frames. As of 2020, carbon fiber for wind turbines makes up 23% of the total end uses of carbon fiber and is the largest industry demand, many of which are manufactured by the Formosa Heavy Industries.[158] Due to the growth of offshore wind turbine manufacturing and global demand for carbon fiber, FPG is planning to expand the production of carbon fiber by 1600 tons at the Renwu industrial park in Kaoshiung.[159]

[156] Interview with Journalist, September 19, 2023

[157] Swancor Renewables, "Swancor Annual Report 2020," see Appendix, Disaster STS

[158] Swancor Renewables, "Swancor Annual Report 2020," 72 (see Qian Xin carbon fiber and its composite technology); Field Notes, October 18, 2023, Energy Taiwan

[159]Peng, Xuanyi "Formosa Plastics spends more than 300 million on expansion project to help increase production capacity" China Times, *Yahoo Market Taiwan,* February 6, 2024.

D. Offshore Wind, Localization Policy, and Government Export Goals

Formosa 1 Wind Fields Visible from the Longfeng Fishing Port in Miaoli County, approximately 25 km Southwest from the Hsinchu Industrial Park

Global pressure for supply chain carbon neutrality is driving major energy consumers to demand greater output of renewable energy, both as a part of individual companies' sustainability goals and as a major point of the Taiwan government's 2050 net zero plan to reduce carbon emissions.[160] As a core piece of the National Sustainable Development Council's 2050 Decarbonization Plan and the 2021-2024 National Development Plan, the offshore wind fields have become a key piece of Taiwan's decarbonization pathway and a draw for international investment. This initiative cites a massive series of offshore wind farms capable of powering Taiwan's large energy consumers with 21.5 billion KWh of renewable energy annually, as well as the coordination by the government, foreign, and domestic investors to establish a wind turbine

[160] Additionally, international organizations such as Greenpeace target microelectronics producers as a main source of carbon emissions, in an effort to decarbonize consumer electronics supply chains. See Greenpeace 2022 "Supply Change: Climate commitments and renewable energy progress by consumer electronics brands and their top suppliers"

production supply network in Taiwan.[161] This has included the development of Taiwan's offshore wind fields, temporarily piloted as early as 2017 with the first Formosa 1 wind field in offshore Miaoli, and later plans to expand the shallow water developments of Formosa 2, and later the deepwater and floating wind fields of Formosa 3 and 4. This development plan has spurred the investment of dozens of foreign companies, at times in partnership with domestic companies. European companies, such as Vestas, Siemens, and Orsted (formerly named Danish Oil and Natural Gas, the state led energy company) have come to Taiwan to supply both technical knowledge and certain specific wind turbine components (such as computers for automated control). Since the construction of Formosa 1 in 2017, these companies have continued to plan and establish essential infrastructure for the offshore wind fields, largely basing their operations in Yunlin, Changhua, and Taichung greater areas.

The construction of these offshore wind fields has been the subject of debate amongst environmentalists and policy makers in Taiwan, and has drawn protest from fishermen in coastal regions. This issue reached national attention when a group of fishermen from Yunlin protested the construction of wind turbines in their local fishing area by sailing out on their boats and blocking construction, citing that they were unaware of the plans prior to construction and were not made part of negotiations between their regional fisherman's association and wind turbine developers.[162] Other fishermen, such as in Changhua, have made similar complaints and have

[161] Executive Yuan Press and Communication Department, "Fully promote offshore wind power - build Taiwan into an Asian offshore wind power technology industry cluster," see Appendix, Disaster STS

[162]Hsieh, Chun-lin and Jake Chung "Fishers from Yunlin county criticize wind turbine project" *Taipei Times,* August 14, 2020.

added interference with oyster and clam cultivation, as drilling stirs up sediment from the sea floor, and vibration and noise can affect schools of fish.[163] Environmental groups, such as Wild at Heart Legal Defence, have pointed to the potential harm that wind turbine construction could have on non-human aspects of the environment, pointing specifically to the Taiwanese white dolphin as an endangered species protected under Taiwanese law. This species has previously been used to contest expansion of the state-led Kuokuang petrochemical development of the industrial parks along the Changhua and Yunlin coast, as its habitat is a narrow strip of coastline that would be heavily impacted by coastal development. On an educational dolphin watching tour at the site of Formosa 1 wind farm, a professor told our group that the developers write off concerns about turbine operational noise by saying the dolphin can simply go to another area of the coast, but expressed that "if the plan is to build wind turbines along the entire coast, where are the dolphins supposed to go?"[164] Concerns about fishing access, seafood farming, and environmental disturbances have received significant attention amongst scholars, activists, and politicians, who are interested in negotiating with developers to bring adequate compensation to those affected by this aspect of energy transition.

As a key part of the wind farm development, the government has mandated that of the materials used to construct and install these wind fields, 60% of this material must be sourced domestically. This policy, often called the 'localization policy' or more formally the 'industrial

[163] "Fishers and wind developers need to talk" *Taipei Times*, September 11, 2023.; Fisherman in Yunlin have also noted that this offshore development may have a long term effect on fishing and aquaculture, and compared it to the changes in current and nutrient flows they observed following the construction of Liuqing. Field Notes September 13, 2023.

[164] Field Notes, September 15, 2023

relevancy policy' is part of an effort to build out Taiwan's local wind turbine manufacturing supply chain, and cement Taiwan as a competitive player in the global wind turbine industry. In phase 3.1 and previous stages of wind field development, the Ministry of Economic Affairs (MOEA) issued a list of products that were required to be sourced from Taiwanese industries, specifying 25 specific items across 5 categories, including electricity facilities, underwater foundation, turbine components, maritime engineering services, and engineering design services.[165]

At times, the coordinated protectionism of the localization policy has become a point of tension for the foreign wind developers. In a regular meeting organized by the European Chamber of Commerce, one developer stated that Taiwan "can't keep the industry islanded from the rest of the world" and that the government should work to "ensure affordable green energy cost for Taiwan's industry" by keeping costs as low as possible.[166] "We know that the goal [of the MOEA] is to create an export hub for offshore wind" another committee member chimed in, but agreed that the localization policy was making the cost of wind in Taiwan uncompetitive with other regions. Others speculated on developing optional conditions for the supply chain, including a comparative point based system that would reward developers who sourced more materials from Taiwan. Within three months of this meeting, this point based system was adopted into the 3.2 phase offshore wind development scheme, allowing for developers to pick and choose which components

[165] "Local sourcing focus in new offshore wind project auction" *Focus Taiwan*, November 10, 2023.
[166] Field Notes, European Chamber of Commerce Taiwan Wind Energy Committee Lunch, September 6, 2023

they will source from Taiwanese companies, but as of writing the requirements of the minimum 60 percent remain in place.[167]

These requests for lower costs are typically regarded as standard corporate logic, where competition between firms drives down prices of necessary inputs. The compromise can be seen as a way to partially ameliorate these contentions from developers as the government maintains its goals of producing infrastructure for a global wind turbine export hub in the Changhua industrial parks and the Taichung port. At the same time, these localization restrictions have created hurdles for developers that have become one of the main complaints and delays for wind turbine manufacturing. Everything from the undersea cables, steel stands, turbine foundations, motors, and turbine blades are to be produced domestically by companies with previously limited capacity for this type of production, while much of the technical components remain sourced from abroad, such as the computer controllers that measure and optimize wind turbine speed and energy production.[168] The difficulty of profitability within these requirements came to public attention when a supplier attempted to bypass these domestic production constraints by importing half-completed offshore wind turbine stands and claiming they were produced domestically.[169]

As foreign companies seek profitability within the localization policy, and domestic companies scramble to increase capacity to produce the necessary pieces for turbine manufacture, an

[167] European Chamber of Commerce Taiwan "LCI-PWC workshop on offshore wind energy" November 22, 2023. Accessed June 18, 2024 https://www.ecct.com.tw/lci-pwc-workshop-on-offshore-wind-energy/

[168] Field Interview with representative, September 10, 2023, Semicon Exhibition Taiwan.

[169]Of the 105 wind turbine foundations produced at the Xingda Port, only 6 were actually produced domestically. See the Control Yuan Investigation report from July 6, 2022, Accessed June 18, 2024 https://www.cy.gov.tw/CyBsBoxContent.aspx?n=133&s=17940

independent wind energy supply chain in Taiwan has developed slowly since the first Formosa 1 wind field started construction in 2017. In April 2022 the first domestically produced wind turbine blades came to fruition, constructed by Tien Li Wind Technology in partnership with Vestas, later producing 100 blades by August 2023.[170] This has emerged alongside slow advancements in wind energy terminals and construction of manufacturing hubs in the Changhua industrial zone, as well as build out of wind turbine blades in the Taichung port.

The government vision of a renewable energy-focused industrial park and port, coupled with their localization policy and coordination with foreign developers, is familiar as a form of industrialization within Taiwan's recent history. As previous chapters have explored, early stages of petrochemical industrialization were as part of a strategy to supply materials to an emerging export market for plastic products, as well as to supply fuel and military technologies to the KMT military forces. Coordination of upstream industrial production based on demands to lower its cost create new incentives and conditions for materials producers to consider expanding technically specific applications of petromaterial uses in the production of these technologies. In the case of wind turbines, these demands to lower costs will be felt in the bottom line of petrochemical producers who manufacture the carbon fiber, epoxy, and other plastics necessary to make the turbine blades, motors, and housings. The upstream petrochemicals of these components are produced in large petrochemical facilities that are interdependent on the production of other chemicals, the vast

[170] Huang, Annie "Vestas, Tien Li produces 100th wind turbine blade in Taiwan" *Digitimes Asia*, August 14, 2023.

majority originating from the processing of refining oil and cracking naphtha in large petrochemical facilities.

E. Technical Specificity

Through this localization policy, a domestic materials supply chain has developed to provide materials for wind turbine manufacture, with a notable focus on materials supplied by the 'old' manufacturing industries. As an example, the wind turbine blades, which are made up of a composite material of interwoven carbon fiber set with an epoxy resin, have driven the growth of the company Swancor since its inception in 2016. This company has developed resins that are specific to the demands of wind turbine manufacturers, and has notably entered the global market as a key supplier. They have also partnered with Formosa Plastics Group to source their carbon fiber, which they then sell to wind energy producers.[171] Both of these materials essential to the lightweight construction necessary for modern wind turbines, are supplied interwoven into the petrochemical industrial array of modern Taiwan.

Carbon fiber, which is produced through the polymerization, spinning, oxidation, and carbonization of acrylonitrile (AN), is a lightweight alternative to fiberglass and allows for longevity of turbine operation.[172] Despite the carbon fiber manufacturing process being relatively intensive in carbon emissions, manufacturers calculate that the reduction in fuel consumption in

[171] Swancorp Renewables, "Swancor Annual Report 2020," See Appendix, Disaster STS
[172] Formosa Plastics Group, "FPG Tairylan Division - Tairyfil Data Sheet", See Appendix, Disaster STS

end-use transportation applications offsets the carbon intensity in fuel reductions.[173] The process of manufacturing carbon fiber is part of the interdependent network of petrochemical production, stemming from a long chain of reactions of crude oil refining and naphtha steam cracking to produce the acrylonitrile feedstock propylene. Acrylonitrile is also used for a variety of midstream applications including the production of n-butanol, a popular industrial solvent. Formosa Plastics is the only producer of carbon fiber in Taiwan, some of which is produced at the Liuqing complex in Mailiao, Yunlin, an area known to have elevated cancer rates correlated with emissions from the plant.[174] In response to demands for carbon fiber, Formosa will increase production at their facility in Renwu industrial park in Kaohsiung. Formosa Plastics and Swancor also operate a joint venture corporation called Sunwell, that has carbon fiber composite assembly sites in Nantou, Taiwan and Jiangsu, China.

Acrylonitrile production was originally expanded in Taiwan to supply upstream feedstocks for the production of ABS polymer and styrene acrylonitrile (SAN) polymer plastics. In 1978, CPDC established a plant to produce acrylonitrile in the Dashe industrial park to supply materials for synthetic textile production, namely acrylic fibers that can be formed into yarns for clothing, knitwear, bedding. This development was part of the backwards compatibility initiative within the petrochemical industry that established access to upstream feedstocks in response to downstream demand. In this case, CPDC authorized patents from Standard Oil of Ohio to produce

[173]Shioya, M., and T. Kikutani. "Synthetic textile fibres: non-polymer fibres." In *Textiles and fashion*, pp. 139-155. Woodhead Publishing, 2015; See LCA report by the Japanese Carbon Fiber Manufacturers Association

[174] Yuan, Tzu-Hsuen, Yu-Cheng Shen, Ruei-Hao Shie, Shou-Hung Hung, Chen-Fang Chen, and Chang-Chuan Chan. "Increased cancers among residents living in the neighborhood of a petrochemical complex: A 12-year retrospective cohort study." *International journal of hygiene and environmental health* 221, no. 2 (2018): 308-314.

acrylonitrile monomers through mixing of ammonia, propylene.[175] Now, access to this chemical has allowed for new application of the fiber technology that has created new properties and possibilities for carbon fiber use in wind turbine blades.

To create the shape and durability necessary for long term use and anti-weathering properties of wind turbine blades, woven carbon fiber is cured with an epoxy resin that creates a form-fit composite material. Epoxy resin is typically composed of a vinyl ester and often has additional reactants added to it to give it these and other specific qualities. The Swancor line of resins, including their brand Swancor Hyver, offer specific qualities for different aspects of wind turbine construction. These types of chemicals are part of a larger category of petrochemical products called thermosets, with increasing industrial applications. In combination with fibers, epoxy can be used to create lightweight and strong materials called composites, which are used in an increasingly large amount of industrial applications in the transportation sector. Swancor's line of epoxy resins are considered to be a notable result of the localization policy, in which a new domestic manufacturing company expanded to become a global supplier of Vestas and other turbine manufacturers, originally due to the technical suitability of the epoxy products amongst domestic suppliers.[176]

These conditions are not limited to wind turbine blades. In addition to upstream expansion, the design capabilities necessary to improve the functioning and conditioning of solar panels is also

[175]Wang, Qi and Taiwan Panorama"The Acrylonitrile Plant of CPDC - A new force in development of synthetic fibers industry" See Appendix, Disaster STS

[176] Interview with Journalist, September 19, 2023. See also: Mason, Hannah "MHI Vestas wind blade materials to be sourced in Taiwan" *Composites World*, May 16, 2020

being researched within FPG. At the Energy Taiwan 2023 conference, Formosa Plastics demonstrated their materials and contracting aspirations to house and install solar panels developed by Sun Rise Energy and Technology Corporation.[177] They demonstrated their low cost materials for floating solar grids, including PVC piping and lightweight aluminum that provide a weather protective case for solar PV panels. They bolster access to material patents for specific materials that are layered within PV panels themselves, specifically for Taisox EVA and Taitillin PET films for coatings.[178] Formosa plastics also demonstrated their initiative in developing dye-sensitized PV cells, where a chemical additive can increase productivity of indoor cells to increase solar energy yield.[179] At the same conference, a downstream textile producer demonstrated their implementation of state research in flexible solar PV fabrics, a proprietary technology developed in ITRI and leased to a private company to produce portable, rollable solar textile mats. A representative from a downstream producer showed me their specialization in small rubber spacers to be placed in the cracks between solar panels, giving me a small link of the soft rubber material to take as a sample.[180]

These components each demonstrate a certain capacity of petromaterial development to enhance or enable the design qualities necessitated for the renewable energy technologies that enable an ecomodern imaginary of the energy transition. The lightweight and durability of wind turbine blades, the housing of floating solar arrays, and the chemical and material additives to solar

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[177] Field Notes, October 18, 2023

[178] Field Notes, August 18 2023, Formosa Plastics Museum

[179] Formosa Plastics Group "Formosa Dye Sensitized Cells Flyer," see Appendix, Disaster STS; Field Notes October 18 2023

[180] Field Notes October 18 2023.

PV are enabled only by access to a diverse array of petromaterials. This technical specificity is generated currently through research and development of the qualities of petrochemical products, influenced over years of industrialization, that enable these materials to exist alongside technologies that would imbue alternative fuel inputs. For the oil business, many view this as the materialized future of the industry.

IV. Plastic Leakage: Problems of Petrochemical Production

This chapter explores externalized aspects of the petromaterial system through a series of ethnographic essays. First, I examine the implications of circularity initiatives through a description of a chip recycling showcase, to examine how the recycling of valuable materials is an act of salvage that lacks capacity to account for the outflow of all materials from its system. Mah (2021a; 2022) discusses how circularity has become a buzzword within the plastics industry to "future proof" it against concerns over the environmental limits of plastic waste. However, actual implementations of this system typically can only retain materials that are of value as the next input, continuing to rely on a steady stream of technical outputs from the system. Through a review of some of the initial design philosophies of plastic circularity, this leakage violates the initial principles of design circularity, in which technical nutrients are to be managed as strictly separated from biological nutrients and ecological systems.

The second essay explores how plastic waste is generated at multiple scales in both the production and end use, and the way that microscopic plastic waste has become embedded in biological functions. Through a 'rogue' sampling of water containing plastic waste outside of Liuqing, I use narrative to evaluate the multiple scales at which the petromaterial fabric of life has become part of our own biological systems. This serves as evidence for the scale of the problem that circularity initiatives hope to solve. The third essay is based on observations while accompanying the Center for Innovative Democracy in the fenceline communities of Kaohsiung's petrochemical cites. These stories serve as narrative examples of the way that petrochemical production relies on a similar logic of leakage in air pollution that shifts a chemical burden to fenceline communities. I examine these excerpts alongside notions of a sort of "biological citizenship" that is produced to create the necessity of sacrifice for the 'fabric of life' materiality of modernity.[181]

Overall, these excerpts point to the extreme infeasibility of the petrochemical industry in managing the outputs from its material system, implicating the assumptions of ecological modernization in improving the relationship between humans and environment. Refined fossil fuels, greenhouse gasses (GHGs), hazardous chemicals, and feedstock plastics are, mistakenly or otherwise, are outputted from this system affecting fenceline communities, all biological systems and global climate change at multiple scales. Considering consumer plastic waste also as an output, the geography of this system's toxicity can be extended to literally everything on the planet. In regulating, managing, and cleaning up after this industrial system of fossil material, we must consider the full implications of reliance on these mechanisms of production and the feasibility of its theoretical circularity and dependence on fossil material inputs. This system is thus hopelessly far from being closed, let alone circular. Initiatives in circularity instead prioritize a theoretical separation of technology from a greater environment over initiatives that would address the unequal burden of leakages from these systems.

[181]Petryna, Adrian. *Life exposed: biological citizens after Chernobyl*. Princeton University Press, 2013; See also Huber, *Lifeblood*; Hanieh, "Petrochemical Empire"

A. Circularity Disguises Salvage and Leakage: "Where should a computer be in the natural cycle?"

Nearing the end of my fieldwork period, I attended an invitational meeting for Taiwan green party members and interested participants to see how a computer repair and recycling center was implementing aspects of 'circular economy' into their business model. The meeting was arranged and sponsored by the Swedish Chamber of Commerce in Taipei (SCCT) as part of any initiative to prevent e-waste and stimulate upstream recycling within the tech industry. During presentations, a member of SCCT cited examples of conflict minerals and the toxic mismanagement of e-waste, such as open pit burning of European e-waste in Ghana, as major evidence for the necessity of social responsibility within this process, and stated that recycling should only be viewed as a last resort. "We don't really know where things end up," he said, but by offering material sourcing certification they could begin to address this problem. [182]

Yet, in this case, they were happy to showcase the efforts of this company and its successes in refurbishing semiconductor chips, extending the life of this circuitry to be used and resold in another laptop computer. A presenter from the company described how they were stimulating responsible consumerism through the repair industry. He said that through recycling the company was saving water and reducing carbon emissions by reducing demand for new chips while creating jobs in an emerging industry. The company was following a circular design guidebook for

[182] Field Notes November 25, 2023

electronics and appliances, which offered solutions for recycling everything inside of a computer; all that would be left as waste was the plastic shell.

After the initial presentations, we suited up in lab coats and hairnets for a tour of the recycling facilities, which included approximately twenty workers in the same lab coats and hairnets seated at desks. They skillfully dissected circuit boards, applied various chemical solvents and heat to detach the chips, moved the chips through specialized machines in a process called 'reworking,' and resoldered the chips to a new circuit board, ready to be used again. Throughout the facility there were dozens of stacks of laptops at various stages of disassembly, including one room where approximately 25 boxes of circuit boards were deemed unrepairable, waiting for disposal. The long term goal of the circular economy model is to have fully compatible materials used for recycling across all stages of production, but for now methods for recovery of many materials are not possible or feasible, especially for plastic housings and components.

As we returned to the main room, the presenters polled for questions from the audiences. One woman, an American who had lived in Taiwan for decades and had purportedly started permaculture initiatives throughout Taipei, raised the point that while recycling of computer chip components was commendable, the idea of a 'circular economy' that was commensurable with with ecological and biological cycles was not necessarily being demonstrated by this company. She described the process of how many large scale tech recycling centers operate in Taiwan, how whole appliances are crushed into rubble and their valuable metals picked out by hand or by magnet, and how a mess of heterogeneous waste products are generated within this process. She asked the presenters how they were designing for circularity within a greater nature, as opposed to focusing on waste as a resource from which value could be extracted. In response to her point, the presenter who had earlier discussed e-waste management curtly responded "where exactly should a computer be in the natural cycle?"

I employ this excerpt not as a critique of this particular company, the SCCT, any of the participants, or chip recycling in general. Rather, this comment from this presenter serves as evidence of a controversy within environmentalism about the relation of technology of materials with biological cycles. Within the development of a circular economy in industrial production of technology, the system must reuse outputs, emissions, or products as inputs back into the system of production, but the materials do not have to be commensurable to natural cycles outside of the system.

This is evidenced by early works to map out circularity in industrial systems, such as McDonough and Braungart (2002), who call for a reconfiguration of design principles that reconsiders the role of materials beyond their initial use. They review the origins of industry and the consequences of the materials that have come along with it, as well as their reliance on export and flow in global trade networks and a reliance on a "seemingly endless supply of natural 'capital'" as creating the design incentives that have led "crucial omissions and devastating consequences" of industrial modes of production."[183] They critique the shortsightedness of what they call the "cradle-to-grave" pathway of material objects as a product of "universal design solutions" and "the

[183] McDonough, William, and Michael Braungart. *Cradle to cradle: Remaking the way we make things*. North Point Press, 2002. 24-6

application of the chemical brute force and fossil fuel energy necessary to make these solutions 'fit'."[184] Instead, the petrochemicals (fossil fuel and materials) necessary for this energy production in the brute force model, as "finite sources of energy" should be "preserved for emergencies, then used sparingly" in situations that demand petrochemical materials, giving medical demands as an example.[185] To do so, the products that utilize these materials must be designed with the material's future utility and the safety of the user in mind, stepping away from "crude products" that rely on toxic supply chains and can lead to user harm. Environmental regulation has looked to mitigate these effects, but instead of questioning the afterlife and production design intentions of the product, has instead looked to regulate "eco-efficiency" in producing less pollution and toxic substances from the "old, destructive system."[186]

McDonough and Braungart (2002) use this critique of efficiency to demonstrate the value of a design and user oriented method of production, in which environments are seriously considered and materials are willingly produced at higher costs to prioritize reuse. They envision an "eco-effective" reality that, through careful design, can simultaneously provide a world of abundance and ameliorate both ecological degrative aspects of production and the social conditions that come from both production and use. As an example of their design strategy, they develop a durable plastic resin on which the book was printed that serves as a 'technical nutrient' to be upcycled in later industrial processes. This is differentiated from 'biological nutrient,' which serves as the basis for ecological processes. In the discussion of mass produced book materials, they

[184] Ibid, 27-31
[185] Ibid, 32
[186] Ibid, 62-3

view this disintegration of products made from such materials as ineffective within the long-term strategy of 'upcycling', as the degradation of materials made of both 'technical' and 'biological' nutrients is ineffective design and can only be 'downcycled,' and is often mixed with hazardous industrial chemicals to improve durability. By offering this separation of nutrients as a solution, their eco-efficient paradigm can exist without producing "monstrous hybrids'' of "cradle-to-grave designs."[187] To manage the reuse of technical nutrients, they must be separated from a greater environment and contain design qualities that allow for their continued functionality.

Circularity, in the sense of recycling technical nutrients back into the system, instead must rely on an industrially managed separation from ecological cycles. Yet in the context of the global microplastics crisis, in which technical nutrients have essentially broken down to microscopic size and have become embedded within nearly all ecological systems, there is little hope for achieving a truly circular system. Recycling and reuse of valuable technical nutrients is the primary goal of many circular initiatives, but the responsibility of managing plastic at all scales has yet to be technically blueprinted, let alone designed and implemented. The goal of industry is not to make industrial cycles compatible with natural cycles, but to create a system of management that maintains their separation.

However, the separation of a nutritional cycle of industrial production relies on the creation of a social space that is completely separated from the natural world. This disambiguation of 'technical nutrients,' serviced by a social disembedding of 'technical nutrients' from its material

[187] Ibid, 98-9

substratum, creates an imaginary that can exist completely separated from natural systems of production. The development of technology and circularity within this system would thus necessitate a permanent severance from natural systems, in order to truly achieve circularity. This conceptualization of plastics demonstrates it as indefinitely durable because they are incommensurable with a greater environment. It is not because the technological world is compatible with the biological, but that it is a material system that is completely incompatible with biological systems. Paradoxically, plastic's design strength is its non-biodegradability that separates it from ecological systems that circulate biological nutrients.

A not so circular economy. Energy Taiwan October 10, 2023.

Instead, what this circularity initiative demonstrates is a cycle of leakage and salvage. Circularity, as it is translated into modern industrial production, is unable to account for the flows of waste that come out of its system, and can only recover what is deemed valuable through reuse.

What a perfectly circular system of 'technical nutrients' would necessitate is instead intimate control over the flow of leakage from the system. It is this reality that allows for messaging about the importance of consumer waste management and recycling to persist. At an annual gala for the Taiwan Plastic Forum, the chairman of a research institute told the crowd that "plastic has no pollution, it is our habits that have pollution" in response to a question about the problems of traditional plastics.[188] As Mah (2022) has noted, the industry has been reluctant to embrace the 'zero-waste' aspects of circularity, instead opting for emphasis on recycling and consumer waste management strategies.[189] The industry has historically preferred to put the onus of managing plastic waste on consumers, who make conscious efforts to recycle as part of their responsibility for using plastic products.

For many environmentalists, full consumer responsibility for plastic waste is absurd, as it disqualifies the sheer scale by which plastic waste has become embedded in ecological systems and puts an onus on individuals to manage the global plastic crisis. Liboiron has described this as a "scalar mismatch" of "purity activism" in which conscious efforts to recycle misses how plastic will

[188] Field Notes, August 2, 2023. Taiwan Plastic Forum.

[189] Mah, Alice. *Plastic unlimited: How corporations are fuelling the ecological crisis and what we can do about it*. John Wiley & Sons, 2022. 54-5

always leak out infrastructures in production and waste.[190] However, from the industry's perspective, the circularity of plastics is strictly dependent on its habits of management.

In Taiwan, this leakage sees another dimension, in that plastic waste is combusted as fuel for many domestic power plants, and is even used as a net zero solution in the energy transition. In the 90s, the Taiwan government implemented a plan to 'recycle' plastic waste through the construction of dozens of trash incinerator power generators. These numbers rely on the complex system of plastic recycling sorting to gather and collect plastic waste, also known as "solid recovered fuel" (SRF), which can then be combusted and turned into power generation. Recently, these power plants that rely on SRF have been running out of viable plastic waste to burn as these incinerators provide for reductions in carbon emissions relative to their coal counterparts.[191] In this way, circularity is limited as plastic waste products are now used as an essential fuel source, where "technical nutrients" are combusted and their byproducts are emitted into the atmosphere, never to be recovered into the system of material.

B. Plastic Leakage: There's Something in the Water

The narrow road was flanked by fish aquaculture farms on either side, approaching the jetty across the industrial canal from the factory. Few people were out today as a Typhoon holiday had been called for Yunlin county the day before. I parked the car and walked to the end of the jetty, close to an inlet where I had heard other activists and researchers had gone to collect plastic

[190] Liboiron, Max. *Pollution is colonialism*. Duke University Press, 2021. 100-3

[191] Ching, Fangwu "How could garbage help Taiwan factories reduce emissions?" *Commonwealth*. Vol. 750, June 27, 2022.

nurdles. From this site you could see the artificial island created for Liuqing, a massive petrochemical facility that contains a fuel oil refinery and dozens of subsidiary branches that created different types of plastic and petrochemicals. Somewhere along the production line, these nurdles were emitted from the factory and lost below the surface of the water.

I scooped up some of the water from the corner of the artificial inlet, in a crook along the jetty where the wind had pushed natural debris and plastic trash, presumably left behind by fisherman from the dock along the opposite side of the jetty. This water, clouded with sediment, contained a litany of materials; small bits of wood, indiscernible dust and sediment, styrofoam, rubber, and multi-colored bits of plastics in different sizes, broken and weathered by the crashing waves against the concrete blocks. Liuqing's lights flickered on, smoke stacks billowing in the background, and as dusk arrived through the post-typhoon mist the only discernible sound were the wind turbines whirring loudly overhead.

The rogue water sample in question.

Upon further examination of the water sample, the sheer variety of plastic was astonishing. Different shapes and chemical compositions of plastic material were exhibited in various states of physical and chemical breakdown. A large piece of polystyrene floated on the surface of the sample, large pink pieces of thin plastic and a blue chunk of rubber-like material floated alongside. Upon closer inspection however, even smaller pieces of plastic were visible amidst small bits of grass and clumps of sediment. Small blue-green specks had weathered down to less than one centimeter, initially appearing as sand or rocks to the naked eye.

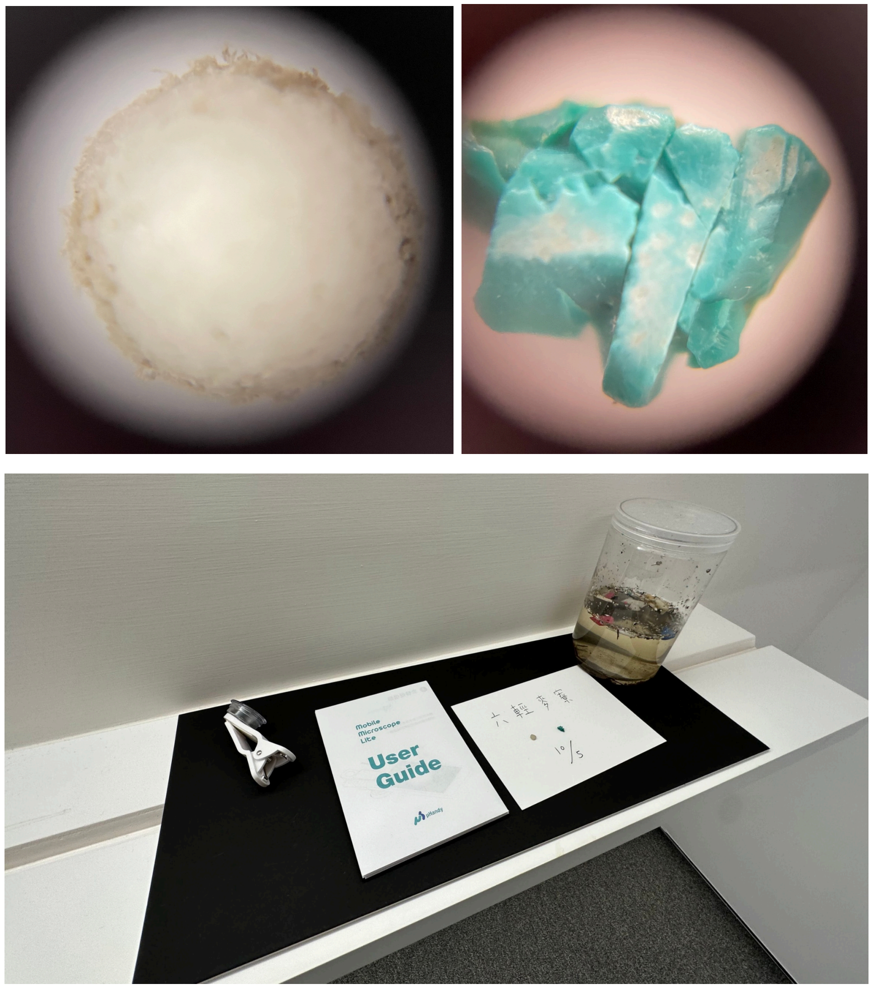
Small translucent pellets were clearly visible floating amongst the plastic waste and natural debris. These pellets, often called nurdles amongst pollution monitoring activists in the US, are one of the base products created in plastics factories. These pellets can be shipped from the refinery to downstream manufacturers, where the pellets are then melted and reformed into any shape or object necessary. Different types of pellets with different material qualities can be turned into any shape of plastic products, melted down and formed into bottles, housing for electronics, 3-d printed components, and fibers for textiles. These small white orbs, however, had escaped from the factory floor and made their way to this inlet, caught in the surf for an unknown amount of time. There, they had joined plastic pieces that had come from finished products, as waste left behind at the jetty.

These same plastic pellets have been an object of significant legal importance in the United States. Activist Diane Wilson noticed these pellets beginning to accumulate in the wetland areas outside of the Formosa Plastic facility in Seadrift, Texas, where she began collecting and documenting them with teams of concerned community members. In 2019, Wilson's long term efforts to archive the plastic nurdles expelled from the PVC factory served as significant evidence in the 50 million USD settlement against Formosa, the largest settlement against an industrial polluter under the Clean Water Act. Though these pellets continue to be released by the factory, Formosa now faces fines and penalties upon evidence of pellet release. However, the work of monitoring and cleaning up plastic pellets is ongoing, enabled in part through the expansion of Wilson's Nurdle Patrol and new fishing cooperative.[192]

In a similar logic to the emissions from combustion of fossil fuels and petrochemical processing, the industry also relies on a type of leakage of fossil material into the environment as an

[192] Erdensanaa, Delger "Diane Wilson on Fighting Plastic Pollution, Losing Everything and Gaining Her Soul" *Texas Observer*, April 24, 2023.

essential part of its production. The industry emits plastic waste at production stage and avoids responsibility for waste from consumer plastics as an essential mechanism of profitability, but these externalities are rarely internalized by the company itself. Even when legal mechanisms are in place to dissuade their pollution, the logistics of production are unable to accommodate or the companies are otherwise non-incentivized to reduce the pollution itself. This type of pellet pollution is not even the main subject of concern within plastic regulators; rather it is the externalization of the health effects of plastic waste as they break down into infinitely smaller pieces, commonly known as microplastics.



The water sample displayed as part of the "Current-Wave" exhibition in Taipei, Nov 4-5 2023. The small magnifying glass affixed to a cellphone camera can be used to look more closely at the plastic particulates. On the upper left is a nurdle released from the Liuqing factory, on the upper right is a weathered piece of microplastic, presumably from consumer waste.

Microplastic pollution has received significant media attention in recent years. Defined as any plastic particulate smaller than 5 millimeters, these particles have been found nearly everywhere on planet: in the Mariana Trench,[193] in Antarctic snow,[194] and at the peak of Mount

[193] Peng, X., M. Chen, S. Chen, S. Dasgupta, H. Xu, K. Ta, M. Du, J. Li, Z. Guo, and S. Bai. "Microplastics contaminate the deepest part of the world's ocean." *Geochemical Perspectives Letters* 9, no. 1 (2018): 1-5.

[194] Aves, Alex R., Laura E. Revell, Sally Gaw, Helena Ruffell, Alex Schuddeboom, Ngaire E. Wotherspoon, Michelle LaRue, and Adrian J. McDonald. "First evidence of microplastics in Antarctic snow." *The Cryosphere* 16, no. 6 (2022): 2127-2145.

Everest.[195] These plastics are shed into the environment and degrade at several stages in their use, particularly from cosmetics, cleaning products, packaging, dust from tire abrasion, and washing synthetic textiles.[196] Living things at different trophic levels consume these plastics, which then can bioaccumulate through the food web at higher trophic levels and leach chemicals and metals long after ingestion. In humans, microplastics are found in placenta,[197] the lungs,[198] and have been found penetrating across the blood-brain barrier.[199] Plastics have also alarmed geologists by forming new rock formations, dubbed "plastiglomerates,"[200] as well as archaeologists who have located plastic intrusions into pre-industrial dig sites.[201] Through anthropogenic forces, plastics are everywhere, leading many to call for shifting the name of our epoch from anthropocene to 'plasticine.'

In 2022, the fifth session of the United Nations Environmental Assembly in Nairobi unanimously passed a resolution to address the plastics crisis and create a legally binding

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[195] Napper, Imogen E., Bede FR Davies, Heather Clifford, Sandra Elvin, Heather J. Koldewey, Paul A. Mayewski, Kimberley R. Miner et al. "Reaching new heights in plastic pollution—preliminary findings of microplastics on Mount Everest." *One Earth* 3, no. 5 (2020): 621-630.

[196] Ryberg, Morten, Alexis Laurent, and Michael Zwicky Hauschild. "Mapping of global plastic value chain and plastic losses to the environment: with a particular focus on marine environment." (2018). 46-50.

[197] Ragusa, Antonio, Alessandro Svelato, Criselda Santacroce, Piera Catalano, Valentina Notarstefano, Oliana Carnevali, Fabrizio Papa et al. "Plasticenta: First evidence of microplastics in human placenta." *Environment international* 146 (2021): 106274.

[198] Amato-Lourenço, Luís Fernando, Regiani Carvalho-Oliveira, Gabriel Ribeiro Júnior, Luciana dos Santos Galvão, Rômulo Augusto Ando, and Thais Mauad. "Presence of airborne microplastics in human lung tissue." *Journal of hazardous materials* 416 (2021): 126124.

[199] Shan, Shan, Yifan Zhang, Huiwen Zhao, Tao Zeng, and Xiulan Zhao. "Polystyrene nanoplastics penetrate across the blood-brain barrier and induce activation of microglia in the brain of mice." *Chemosphere* 298 (2022): 134261.

[200] Queiroz, Sergio. "Brazilian researchers find "terrifying" plastic rocks on remote island." *Reuters* (2023)

[201] Rotchell, Jeanette M., Freija Mendrik, Emma Chapman, Paul Flintoft, Ian Panter, Giulia Gallio, Christine McDonnell, Catriona R. Liddle, David Jennings, and John Schofield. "The contamination of in situ archaeological remains: A pilot analysis of microplastics in sediment samples using μFTIR." *Science of the Total Environment* 914 (2024): 169941.

mechanism to end plastic pollution.[202] Another resolution from this session created the Intergovernmental Negotiating Committee (INC), comparable to the Conference of the Parties (COP) for climate change mitigation, aiming to structure an international legal framework to regulate plastic waste and products.[203] While these resolutions show significant regulatory promise, it is unclear whether or not these resolutions will address only specific plastic products and additive chemicals, or if they will provide legal mechanisms to regulate primary plastics from which these products are made.[204]

The harmful chemicals often contained in plastic waste cannot simply be avoided through consumer choice and waste management, as they have become ever-present. As Liboiron (2021) has said "if plastics and their chemicals are found in tap water, beer, the Arctic, and fetuses, then the relationships we should be looking at are not at the end of the pipe, but in how plastics go into the pipe to begin with."[205]

Plastic waste, and now microplastics, have been the entry point for many in understanding the palpability and urgency of the plastic crisis. However, these discussions have overwhelmingly focused on plastic waste as the causal force of microplastic pollution, as opposed to the sociohistorical orders that initiate the ubiquitous use of plastic in the first place. In many ways regulation of the plastic crisis will be plagued with similar issues to the climate crisis, in the

[202] United Nations Environmental Program. Environmental Assembly 5 Resolution 14. "End Plastic Pollution: Towards an International Legally Binding Instrument" (2022)

[203] United Nations Environmental Program. Environmental Assembly 5 Resolution 3. "Future Global Environmental Outlook" (2022)

[204] Tilsted, et al. "Ending Fossil Based Growth"

[205] Liboiron, *Pollution is Colonialism*, 102.

difficulty of implementing controls on the continued output of emissions from fossil fuel production and consumption, with regulators instead focusing on developing alternative technologies that can provide a substitute for an accustomed pattern of consumption or a technosolution to a pollution problem. The fossil fuel industry has provided both the energetic and material conditions of the development of modernity, and thus scrutinizing the social and political control this industry has within the context of its own management is paramount for understanding "how the plastics go into the pipe."[206]

C. Toxic Proximity as Biological Citizenship: "the smell has been worse lately"

The air near Liuqing hurts. You can feel it in your throat, and still can feel it even days after you leave. For fenceline communities who live downwind of Liuqing, this experience is an ever present threat, undulating depending on the direction of the wind. This aspect of daily life is the title of a compendium of photos and poems, entitled *When the South Wind Blows*, which captures daily life in Taixi, a small town north of Liuqing.[207] In addition to shots of the coastal and petrochemical landscape, the piece serves as a way of remembering and documenting those who have lost loved ones to cancer caused by air pollution.[208] In Taiwan and globally, living near a petrochemical plant

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[206] Ibid

[207] Huang, Hsu, and Chia-Li Chen. "Displaying and interpreting industrial pollution: A study of visitor comments on 'When the South Wind Blows'." In *The Future of Museum and Gallery Design*, pp. 288-303. Routledge, 2018.

[208] Schütz, Tim. Visualizing Taiwan's Formosa Plastics. *Interactions*, *28*(4), (2021). 50-55.

decreases your life expectancy significantly due to higher risk of cancer caused by air and water pollutants.[209]

The chemical toxicity of the emissions and hazards of petrochemical production create relative conditions near petrochemical facilities that cause ecological harm and increase cancer rates in fenceline communities. Often referred to as "sacrifice zones," the UN defines these areas as "extremely contaminated areas where vulnerable and marginalized groups bear a disproportionate burden of the health, human rights and environmental consequences of exposure to pollution and hazardous substances."[210] Others have said petrochemical facilities impose a "toxic geography" through accumulation of "slow violence" that harms communities through proximity to unhealthy environmental conditions.[211] Residents of these areas are known to have elevated cancer rates, a well documented phenomenon in fenceline communities of Formosa's petrochemical facilities.[212] Returning to the water sample, these fenceline communities are also affected by plastic pollution, both from nurdles directly emitted from the factory and consumer plastic pollution.

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[209]Chen, Ya-Mei, Wan-Yu Lin, and Chang-Chuan Chan. "The impact of petrochemical industrialisation on life expectancy and per capita income in Taiwan: an 11-year longitudinal study." *BMC public health* 14 (2014): 1-8.; Yuan et al. "Increased cancers among residents living in the neighborhood of a petrochemical complex"

[210] A/HRC/49/53: The right to a clean, healthy and sustainable environment: non-toxic environment - Report of the Special Rapporteur on the issue of human rights obligations relating to the enjoyment of a safe, clean, healthy and sustainable environment Jan 12 2022

[211]Davies, Thom. "Slow violence and toxic geographies:'Out of sight'to whom?" *Environment and Planning C: Politics and Space* 40, no. 2 (2022): 409-427; Nixon, *Slow Violence and the Environmentalism of the Poor*.

[212]Yuan, Tzu-Hsuen, Yu-Cheng Shen, Ruei-Hao Shie, Shou-Hung Hung, Chen-Fang Chen, and Chang-Chuan Chan. "Increased cancers among residents living in the neighborhood of a petrochemical complex: A 12-year retrospective cohort study." *International journal of hygiene and environmental health* 221, no. 2 (2018): 308-314.; Fang, Hui-chen, Jung-Shin Ho, Yu-Yo Lin, Yi-Ying Chiang, eds. Yancong zhi dao: Women yu shihua gongcun de liangwan ge rizi 煙囪之島:我們與石化共存的兩萬個日子 [A Smoking Island: Petrochemical Industry, Our Dangerous Companion for more than Fifty Years], Taipei: Spring Hill Publishing, 2019.

While decarbonizing energy sources away from coal will significantly reduce the amount of air pollution from coal combustion, even 'true' decarbonization through renewable energy does not address the air pollutants released as part of the petrochemical industrial process, which are called process emissions. Additionally, communities near petrochemical facilities are put at risk of leaks of toxic chemicals or explosions as a seemingly unavoidable quality of production. While climate change mitigation solutions target carbon dioxide and methane emissions to reduce the impact of global warming from fossil fuel use, there is currently no technological substitute for the petromaterial uses that necessitate a certain amount of benzene, toluene, xylene, sulfur dioxide, carbon monoxide, hydrogen sulfide, or nitrogen oxide emitted during the refining process.

A few hours south in Kaohsiung, I accompanied the Center for Innovative Democracy (CID), a research team at National Chengchi University that is collecting testimonies and data on the experiences of fenceline communities near petrochemical facilities. Interviewing two local leaders in the Dashe neighborhood, a prominent petrochemical corridor of Kaohsiung, they expressed their frustration with their ongoing lawsuit and the time and money they had put into their legal case, where they are suing to attempt to shut down or severely reduce the air pollution coming from the neighboring industrial parks. They lamented the relatively "slower and simpler" industrial transformation they observed in the industrial parks compared to their perceptions of other areas in Taiwan. "The air pollution is the worst around noon," an interviewee told the group, "if I run during that time, my spit looks like an old smoker's." The two residents recounted their children's decision to depart from the neighborhood, and that they ultimately encouraged their children to move elsewhere for their own health. In frustration with the feeling of being left behind in the process of industrial transformation, one asked rhetorically “is the chemical industry’s contribution really that high?”[213]

The neighborhood is located northeast of the Dashe industrial park, which houses dozens of midstream petrochemical producers, including an old CPDC petrochemical facility that manufactures acrylonitrile.[214] A few kilometers south is the Renwu industrial park, which houses a large FPG petrochemical facility that is similarly focussed on downstream refining. The Renwu park is also the site of a Formosa Plastics carbon fiber facility, which is looking to expand their carbon fiber production to meet demand for other niche technical applications, as a business strategy to combat falling plastic product sales at the end of 2022. [215] [216]

The Renwu and Dashe petrochemical industrial parks also used to be home to the Wuqing, or the 5th Naphtha cracker and Kaohsiung refinery established and operated by the CPC. Located in Danzi, Houjing area of Kaohsiung (next to the “oil refinery elementary school” stop on the Kaohsiung MRT), the refinery was established in 1946 on the former site of a Japanese navy fuel refining and storage facility. After decades of protest, this refining and plastics manufacturing complex slowly halted production in 2015 and began the long process of decommissioning. Despite this relative success, the surrounding complex of midstream petrochemical manufacturing

[213] Interview and Field Notes, October 26, 2023

[214] CPDC "Acrylonitrile Safety Data Sheet", See Appendix, Disaster STS

[215] Formosa Plastics Corporation, "2023 First Quarter Operations Performance Summary" 3-4, see Apendix, Disatser STS

[216]Peng, Xuanyi“Green Energy Electric vehicles and Europe’s expansion of military budget; Formosa Plastics, Suncorp, and Nanboa Facilitate Tien Li” *China Times, Gongshang Shibao*, June 1, 2022,.

still creates hazardous conditions for the communities in proximity, through ongoing air pollution, periodic explosions, worker deaths and exposure, and elevated cancer rates.

Less than 1 kilometer away from the Renwu industrial park is a small elementary school, where many worker's children attend school. As part of the curriculum, students learn about air pollution and air monitoring, and have sensors throughout the school to measure air quality. The sensors display red, yellow, or green lights depending on the amount of particulates or other gasses in the air, alerting the students to whether or not they can go outside to play during their outdoor activities, particularly in winter months when air pollution increases. An instructor told us that while the students are personally invested in how the quality of the air affects their activities, ultimately "the kids are used to it."[217] In an effort to engage students on the issue of air pollution and their proximity to the industrial park, the administrators and instructors explained the different ways that they build lessons on air quality into their curriculum. One teacher described how they built mobile air quality sensors from programmable chips and took students to the Formosa plants, where the students would use their sensors to measure air pollution and record the measurements at the front gates. Another teacher described how they had attached these same sensors to a homemade air filter, which the students had crafted in the shape of animals out of paper mache. He brought two as an example and displayed them on the table: one in the shape of a frog, and the other an armadillo, each wired to a small programmable chip that collected the air pollution data. "We can't change the larger environment," a teacher mentioned, but through air

[217] Interview and Field Notes, October 26, 2023

filtration in the classroom and designing curriculum around air pollution and changes in air quality, they could have some control over the "smaller environment."[218]

The CID team has been working on collecting measurement data for a lawsuit against the local government for their allowed levels of pollution from the petrochemical parks. Kaohsiung as a whole has a long history of civil activism against naphtha crackers and air pollution from the petrochemical industry.[219] While the companies in the Dashe and Renwu industrial parks point to their overall reductions in emissions over time, local residents are unsatisfied with these claims, citing the difficulties with knowledge of chemical storage and risk of explosions as ongoing issues. Despite the claims of improvement in emissions from manufacturers in the industrial parks, longtime residents can tell that "the smell has been worse lately" in response to unannounced changes in production and storage of petrochemical materials.[220]

218 Interview and Field Notes, October 26, 2023.
219 Ho, "Resisting Naphtha Crackers"
220 Interview and Field Notes, October 26, 2023

These images were captured by the author in a cancer ward of a hospital in the Kaoshiung Municipal Hospital in Siaokang, near Kaoshiung's second industrial port. On the right, an array of flowers are displayed as gifts from local businesses and factories for the photography exhibition entitled "village under the smoke stacks," a photo series of local life and the industrial landscape of Siaogang and Dalin. On the left, a note of well wishes from factory heads at the CPC oil refinery in Dalin and the names of the factory managers and staff.

After the closure of the Wuqing in 2015, upstream demand for petrochemical feedstocks shifted to the CPC owned Dalin refinery in the industrial park near Siaokang, Kaohsiung, and the renovated and expanded third Naptha cracker in Linyuan, with plans to build a new naphtha cracker to replace the defunct fourth naphtha cracker.[221] [222] This industrial zone now supplies upstream ethylene and propylene to the Renwu and Dashe industrial zones, which

[221] CPC, "Downstream Operations", see Appendix, Disaster STS
[222] "CPC Planning new Naphtha Cracker" *Taipei Times,* January 19, 2021.

then refine and produce plastics. While this area is further from the residential areas of Kaoshiung, the effects of air pollution from this industrial park are a toxic but typical part of daily life for Siaogang residents.

The images above were captured in a bustling hospital on the outskirts of the Siaokang industrial park, where the CID team had planned to interview a hospital staff member who specialized in air pollution. In the lobby, a series of photos depicting the Dalin neighborhood were temporarily on display as part of an exhibition between the hospital and local photographers. These pictures highlighted local landmarks and their proximity to the smokestacks from the industrial park. The title of this exhibition can be translated as "the village under the smokestacks," a common phrase for Taiwan communities in proximity to toxic air from petrochemical industrial production. This title was also a slight play on a cooking tradition famous from these regions in Kaohsiung, as several of the images showed Dalin locals lined up to smoke chicken, each with a large round tray that is stacked in a tower over a smoker.

As a show of well-wishes, local businesses and residents had sent large vases with orchids or other ornamental plants to celebrate the opening of the exhibition. These flower arrangements each included cards dedicated to the success of the exhibition, signed by managers of nearby factories. One of these flower arrangements was from the CPC Dalin refinery and the Dalin power generation station depicted in the photographs, and whose smokestacks produce the air pollution that might lead someone to seek treatment in the very cancer ward where the photos were displayed.

This series of observations, from the air near Liuqing, the elementary student's air monitors, to the frustrated locals and the chaos of a busy hospital, showcase the way that life is ever-presently affected by petrochemical pollution. This sense of survival amidst pollution from an imposed regime of industrialization, stemming back to the KMT dictatorship and the US assisted industrialization of Taiwan's plastic production, affects the lives of locals constantly, both socially and biologically. Yet, while this sacrifice is in some way recognized by government officials and even the companies themselves, often through individual monetary compensation on a case-by-case basis, this process is not halted in favor of material production.

This is reminiscent of what Adriana Petryna calls "biological citizenship," by which victims of radiative fallout from the Chernobyl disaster were forced to take on the biological responsibility of technological mismanagement of nuclear energy. Petryna describes biological citizenship as the condition in which "the basic biological existence of populations" of classical citizenship is refuted in favor of the "determination of the international political economy."[223] This process is characterized by a bureaucratic politics of recognition in the medical and legal contexts in which victims attempt to attribute their diseases to dispersed slow violence. While the causal mechanisms of cancer related to air pollution are understood clearly by scientific research, the CID under Wen-ling Tu have sought to collect citizen generated data on air pollution in Kaohsiung and other places in Taiwan, as the causation between local petrochemical pollution and individual negative health effects is difficult to establish as a negotiating tactic between government, industry, and

[223] Petryna, *Life Exposed*, 218.

community.[224] Despite this, the CID has collected a wide variety of qualitative data on the conditions of fenceline communities at sites of petrochemical production in Kaohsiung and other locations in Taiwan, and has been recorded in detail in the online database called the Asthma Files.[225]

Whether it be renewable energy technology or other industrial products demanded for development, the mechanisms of low cost production necessitate that feedstock chemicals are produced at scale and emit toxicity throughout its supply chain. As oil is made into propylene, mixed with ammonia into acrylonitrile, spun into carbon fiber, communities are entwined into the production of this technological materiality, regardless of the material's end use or their explicit resistance. In this way, average people are incorporated into a regime of production that is upheld to produce the material conditions that provide the mechanism for companies to profit, and inadvertently the conditions Taiwan state to continue to reify itself. This proximity of communities to petromaterial industrial production and their ongoing struggles for recognition and justice are testament to the profound contradictions of democratic statecraft. Amidst a militarist logic of protectionism, economic participation necessitates the expense of communities who must sacrifice their health for an abstract good exemplified by petromaterial production. In this way, the bodies of communities on the fenceline are incorporated into an economic project and its necessary material economies.

[224] Tu, "Combating Air Pollution through Data Generation and Reinterpretation: Community Air Monitoring in Taiwan"

[225] See Appendix, the Asthma Files

Yet, the tensions of this order of material production are dismissed with participation in the tedious state making project of Taiwan. Taking the offshore wind fields as an example, the states initiative toward 'green' industrial production through transitioning to renewable energy, dispossession alongside this project of statecraft is visible beyond the source of energy itself. Taiwan can not simply make different products or move production elsewhere, as the unique qualities of their supply niche require localized incitation of 'old' industries to yield the technologies that make up the 'new' industries. The qualities of dispossession from the 'new' industries are visible, as the territorializing of fishing grounds is met with counterreaction and compensation from companies and governments maintaining their investments and trajectories. However, to produce the the components of the machinery that occupies these territories, including steel offshore stands, steel turbine housing, plastic engine components, carbon fiber blades and proprietary blends of weather-proof epoxy, the qualities of the 'old' industries have been enacting a slow violence of chemical dispossession, in which the opportunities for initiatives to change the landscape have been historically refuted.

The challenges of the unique precarity of Taiwanese citizenship also hamper the ability for public calls to regulate polluting industries, as harm to economic function has come to mean a risk to the democratic process and free speech enjoyed in the post-KMT era. This idea was expressed to me throughout the fieldwork period in reference to rhetorics used to prevent regulation of industries that are essential to the economy itself, not just militaristic national security. As these ideas of the threat and violence to way of life at the state level continue to entwine the use of fossil fuels and petromaterials into daily life.

In a way, the flowers from the CPC in the cancer ward could represent an acknowledgement of this, where the company understands its impact and must balance between supporting itself and its community. Alternatively, it could represent a normalization of this toxic geography, where actors may see themselves as local entrepreneurs supporting their community initiatives, a relationship that many petrochemical operations have to promote their own community involvement.[226] As Huber (2013) has said, oil refineries reflect historically specific relations between petroleum and society.[227] Societal usage of the materials produced by this social relationship then also reflect a certain acknowledgement of the sacrifice of fenceline communities. The legacy of US-led and KMT supported petrochemical industrialization and Kaohsiung continues to degrade quality of life for locals, while projecting improvements in material conditions and statehood.

[226]Jobin, "Our 'good neighbor' Formosa plastics"

[227] Huber, *Lifeblood*, 70-1

V. Conclusion: the Social Process of Degrowth

This project has sought to provide historical, technical, and social contexts for the worlds created through the use of oil as a material. The historical conditions of the development and spread of the petrochemical industry have socially and physically locked-in oil use within the conditions that provide materiality of modernity and relative stability of the post-colonial state. The material system is highly problematic, primarily in leakage from its system of fossil production that continues to destabilize the global climate and have embedded petromaterials in the bodies and ecosystems of every living thing on the planet. Yet, we depend on this petromateriality to maintain the technological fixes to the contradictions of capitalism and to develop new technological fixes to mitigate emerging ones.

Returning to the initial question poised by this research, Formosa's simultaneous investments in new plastics plants and battery technology sparked inquiry into how petrochemical capital is positioned to respond to demands of the energy transition. These concurrent developments should question what role companies like Formosa actually play in producing technology deemed essential for decarbonization. As Mah (2023) and Tilsted et al. (2022) have shown, it is clear that petrochemical companies are diverting attention from their carbon emissions contribution to climate change to their emerging role in producing renewable energy technology, particularly as a distraction from the difficulty of decarbonization in the petrochemical industry.[228] However, the petrochemical industry's role as the essential material provider for the production of modern technology is also a reality. If trends like these continue where petrochemical companies invest in renewable energy technology alongside existing petrochemical installations, the role of petromaterials in providing the materiality of the design solutions to the climate crisis risk entrenching a new order of energy and material technologies that do not address some of the inherent problems of petrochemical production and plastic use.

Despite this, there exists an albeit difficult path in which petrochemical production could generate its energy from renewable energy and can be mostly decarbonized. The energetic demands necessary to heat and refine fossil fuels are historically and infrastructurally linked to combustion of fossil fuels, and are difficult to retrofit, as Bauer et al. (2022) have pointed out as a major lock-in to continued carbon emissions. Yet, this infrastructural reorganization is possible in the technological imaginaries of both the industry and decarbonization advocates. The Taiwan government's vision of their Changbin technology ecopark and Formosa's vision for decarbonizing Liuqing speaks to this vision of ecomodern petromaterial production.

The possibility of a de-plastified material system is much more difficult to envision, and the industry pointing to their role in providing the materiality that makes modern technology possible

[228] Mah, *Petrochemical Planet*; Tilsted, Joachim Peter, Alice Mah, Tobias Dan Nielsen, Guy Finkill, and Fredric Bauer. "Petrochemical transition narratives: selling fossil fuel solutions in a decarbonizing world." *Energy Research & Social Science* 94 (2022): 102880.

is based in inconvenient fact. The lock-in of design and knowledge production plus the demands of downstream markets assure that petromaterials will continue to be used in all aspects of commodity production. The mass realization of the crisis of plastic waste and its extension to every aspect of biological cycles raise essential questions about the feasibility of new technosolutions and the necessary control of material flow that would hypothetically make circularity possible. Engaging with the petrochemical industry as a material provider and creator of both the crisis of climate change and plastic waste necessitates a critical interrogation of what role this energetic and material system played historically, and how these configurations might be undone or reconfigured to fit the necessities of sociotechnical order within ecological limits.

This thesis has explored this history in detail through the context of the emergence of Formosa Plastics in post-war Taiwan. Founded as part of a project of US aid to the KMT government, Formosa plastics represented the establishment of a private petrochemical company amidst concerns of the rise of communism in East Asia, as well as market protectionism from the KMT-owned oil configuration of CPC. In response to the oil crisis, the KMT government and Formosa pursued a variety of strategies to secure access to upstream oil resources, and concurrently established an industrial pathway of petrochemical development that emphasized adding value to petromaterials for their application in a wide variety of downstream industries. This emphasis led Taiwan to a prominent role in the global economy, through downstream industries such as synthetic textiles and electronics production that relied on ample petromaterial feedstocks. These same feedstocks are now providing for the design possibilities envisioned by private companies, coordinated by the state toward its net-zero goals.

This material coordination has led to a certain ubiquity of plastic that is socially imbued in the production of new technologies. The widespread use of petromaterials provide the material infrastructure for renewable energy, as well as create the design capabilities for technology that can respond to new crises, while its ubiquity maintains a level of abstraction from its oil material origins. The industrial and consumer applications of petromaterials provide enough potential value for the petrochemical industry that material use alone can eclipse the energetic needs from oil as a fossil fuel. However, this material value of technically specific, high-value chemicals is in turn reliant on a greater system of large-scale refining of oil feedstocks and petrochemical processing for these design imaginaries to exist.

This material system also relies on externalization of byproducts to maintain profitably. Each stage of the petromaterial system, from refining to waste, leaks pollutants into biological systems simultaneously at scales ranging from the planetary to the microscopic. The design ideology of circularity seeks to account for this leakage, but would require a system of management that could never possibly account for all of its 'technological nutrients.' Instead, circularity has been co-opted as a secondary strategy of value-addition that maintains a linear system of production and waste generation, while toxicity is continually externalized.

It is this petromaterial legacy that so often inexplicitly haunts discussions on the limits of the ecological systems to sustain modernity. It is known that synthetic materials affect ecological systems to an unknowable degree, but the possibilities generated by the modern imaginaries are incapable of doing without it. Modern technologies emerged in conjunction with the expansion of petromateriality in a way that could replace calls for systemic redesign, and the crises of petromateriality necessitate a reevaluation of societal relationships to modern technological development. Ecomodernity exploits petromateriality to provide new solutions to the eternal energetic and material disparities created by itself in order to maintain existing systems. The demands of cessation of the system that produces the causes of ecological degradation is to provide a superior system that creates the same possibilities of this materiality. In this way, petromaterial modernity is maintained as the proprietor of forbidden fruit. In the midst of a moment of global environmental movement in which the 'business-as-usual' characteristics of the petromaterials are not challenged in favor of ameliorating global climate change, what new material systems or social orders are necessary to deal with the legacy, ubiquity, and toxicity of petrochemicals?

The process of degrowth would necessitate a thorough interrogation of this materiality as one that upholds ubiquitous consumption and ecological degradation. As early as 1972, philosopher André Gorz coined the term "degrowth" in a debate on the subject of Club of Rome's "zero-growthism," in which he asked if "global balance, which is conditional upon non-growth - or even degrowth - of material production, compatible with the survival of the (capitalist) system?"[229] *The Limits to Growth* would be published by Club of Rome later that year, which popularized the notion that industrial civilization risked collapse at its current rate of growth, based on computer

[229] Timothée Duverger, "Degrowth: the history of an idea," Encyclopédie d'histoire numérique de l'Europe. Accessed: https://ehne.fr/en/node/12253

modeling scenarios of population, technology, pollution, and resource consumption. In the last decade or so, degrowth has come to mean an “equitable reduction ... [of] the materials and energy a society extracts, processes, transports and distributes, to consume and return back to the environment as waste.”[230] A new degrowth economy would emphasize collective ecological self-limitations, a politics of care and resource redistribution, and prioritize use of relatively less sophisticated technologies, in order to resist potential co-option by authoritarian or technocratic regimes.[231]

In the context of degrowth, Saito’s (2022) intervention in Marxist ecology has clarified Marx’s late-life understanding of ecological condition and methodological approach to environmental issues. Saito points to Marx's dialectic of historical materialism as a tool for degrowth, as a method that does not naturalize the societal forces as a necessity that yields ecological crisis. He advocates that this promotes an idea of degrowth communism as a method of interrogation with the materiality and systems of capital accumulation, as a method as opposed to purely an ideological position. This argument says that degrowing is the dialectical response to the social constructivism of modernity, by emphasizing its ecological limits and understanding how capital shifts the disparities of the metabolic rift through time, space, and technologies. It is this process of understanding that characterizes Marx’s original intent in what has become metabolism, as opposed to a constructed system of a world order of quantities that has come to represent studies of industrial metabolism of society.[232]

[230] Kallis, Giorgos. "In defence of degrowth." *Ecological economics* 70, no. 5 (2011): 874

[231] Kallis, Giorgos. "The degrowth alternative." *Great Transition Initiative* (2015): 1-6.

[232] Saito, “Marx in the Anthropocene,” 22-9

Saito (2022) uses this methodological groundwork and review to build categories for how to understand a relationship to materiality, and how to differentiate this materiality from a generalized sense of technology. He draws on the work of Gorz to demonstrate the importance of interrogating technology developed through capitalism as productive forces to be appropriated by the masses or risk subsumption of labor. Gorz differentiates between "open" and "locking" technologies, the latter of which is often developed under capitalism to assure control, limiting potential democratic reconfiguration even under socialism.[233] Saito goes on to say that the development of technologies should "start from scratch" to avoid reproducing these qualities.[234] Ultimately, these categories and methodological intervention serve as an interrogative process that can help determine what material applications, ecological limits, and social orders are necessary for determining sociotechnical needs.

The onus to interrogate existing material systems is because certain aspects of their design quality and production may harbor the legacy authoritarian social orders. Winner (1980) openly asks whether or not social order is inherent within the technology or lends itself to a specific type of social organization, premised in the context of claims from solar developers that large scale solar arrays were inherently more democratic because of the relatively dispersed nature of their operation when compared to the relatively authoritarian systems of nuclear energy production. As an example, he points to the automated tomato harvester to ask if the scale of industrial production is

[233]Ibid 157; Gorz, André. *Ecologica*. Seagull Publishing, 2010, 8-9; Gorz thinks along these lines through Ivan Illich's differentiation between 'convivial' and heteronomous technologies.

[234] Ibid 158

a legacy in itself of political institutions that privilege large scale industrialized agriculture. While these machines were not necessarily the "result of a plot" they became the "embodiment" of a certain social order to small scale farmers.[235] The scale at which the technology operates, in its own right, necessitated a certain spatial application, but the conditions of its design, operation, and the choices of its initial implementation were products of greater political contexts. Winner is saying that while new social arrangements around objects, technology, and artifacts are always possible, they are not inherent. At the same time, certain characteristics of technologies reflect the politics and intentions of previous regimes.

The design legacies of plastics and petrochemical infrastructure will also haunt future applications of "open" technologies. As an example, the microplastics that break down from even the regular use of petromaterial products prevent anything reminiscent of circularity from being possibly achievable. This quality, as an unknown aspect of design with still poorly understood ecological limits, is a social legacy of a system of petrochemical production that externalizes waste to a greater, theoretically infinite environment. Plastic's malleability allows it to shape into any of the criteria necessitated by inventors and designers, and its durability allows it to persist indefinitely. Similarly, the scale of petrochemical production sought to achieve efficiency in production, but also created large webs of pipelines and interconnected systems that necessitated centralized control and continued operation to avoid dangerous malfunction. While not necessarily the "result of a plot," the materiality and social enmeshment of oil becomes an

[235] Winner, Langdon. "Do Artifacts Have Politics?" *Daedalus*, Vol. 109, No. 1, (1980), 127-9

unintended legacy and an obstacle for new social orders, as the decision making surrounding the widespread production and use of plastics have created infrastructural arrangements and waste problems that are difficult to solve in a decentralized manner.

While it seems obvious to say that degrowth would be inherently opposed to petrochemical production, it is also difficult to fully understand what immense pressure this absence of materiality would put on the current expanse of modern society. As David Harvey (1996) mentioned nearly 30 years ago in his critique but ultimate valorization of a "radicalized" ecomodernity discourse: "the demand to cease the production of *all* toxins, hazardous wastes, and radioactive materials, if taken literally, would prove disastrous to the public health and well-being of large segments of the population, including the poor."[236] The challenge to degrowth is not just about how to reorient society in a way that supports an alternative regime of resource use, but also to negotiate with the industrial legacy of previous regimes of authoritarian control. The technological fixes of capitalism now hold the floodgates of ecological rifts back from the populous, and it is this physical and institutional infrastructure that produces crisis and must be interrogated.

This sentiment is echoed by one of the most prominent ethnographers on the contemporary petrochemical industry. Mah (2021) has critiqued degrowth because it avoids "confronting practical dilemmas and conflicts of radical industrial transformation."[237] In the context of the onus for decarbonization, she views the degrowth movement as too idealistic in the way that envisions a

[236] Harvey, David. *Justice, nature and the geography of difference*. Wiley, 1996, 399, emphasis in original

[237] Mah, Alice. "Ecological crisis, decarbonisation, and degrowth: the dilemmas of just petrochemical transformations." *Stato e mercato* 41, no. 1 (2021b): 51-78. 13; Mah (2023) 126-142

"serene" transition away from this system of production, especially in the way that workers in fenceline communities depend on petrochemical facilities as employers. She cites the messy interdependencies of petrochemical lock-ins that have made them "essential to modern life," including projected demand and limitations in industrial reconfiguration. In spite of their legacy, ubiquity, and toxicity of petromaterials, the difficult process of ceasing petrochemical production adds to the imperatives for its continuation. Mah (2023) ultimately makes the case for a just transition that can slowly account for the negatives of petrochemical transformations across multiple scales, while the political project of degrowth "can be extended more tangible and practically within struggles over decarbonization and just transitions"[238] The process of degrowth then must grapple with creating new social constructs, as well as untangling the physical infrastructure and technical interdependencies of petromaterial production. This thesis has sought to understand the scale of these interdependencies of petrochemical production and technology, and the social systems that co-evolved with them, in an effort to chart possible courses of action.

Petromaterials, despite their production being a "locking" system, enable all sorts of social technologies: plastic gloves and masks prevent the spread of disease, plastic bottles transport water for miles, chemical cleaners sanitize surfaces, synthetic textiles clothe the masses, synthetic materials compose new homes, plastic encloses electrical wiring, houses circuitry, preserves water infrastructure, transports food, displays information and is the medium of modern communication, creates lightweight structures that provide energy and transportation, paints

[238] Mah, *Petrochemical Planet,* 140

canvases, et cetera. Yet it is not the materials themselves that act with agency as is phrased, but these materials provide for social functions that are currently not enabled by other materialities at the scale and configuration of modern populations. What makes degrowth so challengings is a conflation of social function with the petromateriality that currently provides it.

Petromaterials not only cloud imaginaries for new social orders, but may also be enabling images of an alternative energy system that does not interrogate the materiality and subsequent reliance on 'locking' systems of petrochemical production. This reality inhibits the goals of progressive wings of the energy transition, as being able to substitute and produce an inherently infinite amount of energy, invoking 'locking' mechanisms of material and technological production. In Malm's *Fossil Capital*, his concept of "return to the flow" examines the contradictions of the potential of renewable energy technology in simultaneously enabling decentralization of energy production, and requiring potential schemes of central planning and nationalization.[239] In many ways, he acknowledges that implementing large-scale substitutions of energy technologies will inherently also rely on previous "locking" systems of material production for their design and implementation, as the push to lower the cost of its implementation puts continued pressure on upstream industries.

For degrowth to avoid entrenching a new regime of energy production amidst a 'locking'' centralized system of petromaterial, the political call for a defossilized energy system should also be the call for a new sociotechnical system of material production. Malm's study of the shift away

[239] Malm, *Fossil Capital,* 367

from water to steam power is supposed to serve as an intimate understanding of how the fossil economy grew, as "a key to understanding and removing the impediments" of a new energy transition. Yet, simply removing fossil fuel obstacles would not bring about new energetic sources inherently, as these technologies are materially constrained. It would necessitate an entirely different, materially and energetically distinct system of production to create and return to these flow technologies.[240] While these energetic sources of flows exist as 'gifts,' technologies that harvest this flow that rely on both decentralized use *and* production are not part of the mainstream imagination for a new energetic system. Social conditions surrounding this materiality can shift, but the necessity of materials specifically generated through the previous regime of energy and material production, their upkeep and production is indefinitely reliant on this system. In simpler words, the return to the flow is being held back, but it is also materially and socially constrained.

If this is the case, what would it mean to "start from scratch" to develop a new technological system to return to the flow? Is it possible without the "locking" technologies of plastic and petrochemical production? Even in Illich's *Tools for Conviviality*, he pragmatically envisions the reappropriation of technologies from modern production that could create "open" design possibilities for future restructuring of society, but opts not to interrogate the materiality of these technologies as an inherent hindrance to this goal.[241] An imaginative project that rejects petromaterials in this design yields a certain deformation of technological possibilities in favor of rejecting the "locking" nature of petromaterial production.

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[240] Ibid 15

[241] Illich, Ivan. *Tools for Conviviality*. Harper and Row, 1975. 23-20

Perhaps “starting from scratch” could reevaluate how material possibilities could be generated from alternative biofeedstock sources, as even the origins of the inventions of plastic materials were derived from cellulose. Though the implementation of bioplastics would have to be small scale to avoid putting pressure on farmed biofeedstocks, these design possibilities of plastic could be reappropriated fully into the domain of conviviality: community organized material production from cellulose could carefully replace essential uses of petromaterials, for example. The onus of this substitution of a new materials economy is not just to avoid the legacy of plastic’s degradation, but relying on alternative social orders of material production could create a new sociotechnical complex that is capable of fostering both production and use of “open” technologies.

As Mitchell has discussed in *Carbon Democracy,* the “social-technical features of the oil industry made it increasingly difficult to build mechanisms of more democratic politics out of the production of oil.”[242] However, while the “locking” and highly centralized technologies of petrochemical production and the social institutions that have developed around oil have path-dependent inertia through, it is unclear that the degrowth of this system must be the end of the benefits of petromateriality. Could oil’s immediate material benefit provide justification to create new social organizations that can manage the production and distribution of petromaterials in a truly decarbonized and equitable system of production? Or do the legacy of the technical qualities of petrochemical production, in its scale, centralization, and leakage make it an impossible system to govern equitably? Part of what this means is understanding how petromaterials are

[242] Mitchell, *Carbon Democracy*, 241, 237

interlinked with a tool for military, economic, and state domination, and how systemic redesign can bring about new social relationships to oil, especially those that prioritize petromateirals' limited use for specific applications deemed completely necessary as a core societal value. Goals for phase out of the current fossil energy system must entertain the future of new oil worlds, where social systems that control petromaterials use are paramount to preventing the industrial conditions that yield systemic ecological impact. What degrowth stands to offer is a vision for a slow adjustment to an alternative material system, but the gravity of this task is procrastinated for the immediate demands for the cessation of new petrochemical projects that would further entrench petromaterials in social function.

As has been said and many have repeated, it is easier to imagine the end of the world than it is to imagine the end of capitalism.[243] An unfortunate addendum is that it is easier to imagine the end of capitalism than it is to imagine the end of oil. Yet, this does not mean that proliferation of new material systems that can combat the ubiquity of petromaterial or its externalities and can replicate their most necessary qualities are misguided, but control over the implementation of this system must be in the hands of the populace. Strategies toward the goals of fossil fuel phase out are admirable given the urgency of climate change but limited if the systems for democratic control over its production do not account for the state's existential requirement of economic legitimacy. As opposed to seeking win-win solutions that preserve and mitigate the contradictions of capitalism, the focus must be on redesign of material systems to fit the societal demands governed

[243] Originally attributed to Slavoj Zizek and Frederic Jameson, this quote was repopularized in the work of Mark Fisher.

by an “open” technological system, one that prioritizes limited use across production and control via communities that exist in proximity.

Appendix

Archival Sources

Disaster STS

This project examined a variety of documents across web platforms, as well as documents collected in person. I accessed documents and information stored on the Formosa Plastics Global Archive, and contributed artifacts that I collected throughout my fieldwork and research. These documents are listed below and stored on the Disaster STS Network under the project title of this thesis, "Plastic Entwined." To access these documents, please visit the links listed in the citations below. To learn more about the archival project, read the essay here: https://disaster-sts-network.org/content/formosa-plastics-archive/essay

China Petrochemical Development Corporation, "CPDC-(大社)001 Acrylonitrile Safety Data Sheet July 11 2007", contributed by Rex Simmons, *Project: Plastic Entwined, Disaster STS Network, Platform for Experimental Collaborative Ethnography* https://disaster-sts-network.org/content/cpdc-大社001-acrylonitrile-safety-data-sheet-july-11-2007

China Petroleum Corporation, "Downstream Operations", contributed by , *Project: Plastic Entwined, Disaster STS Network, Platform for Experimental Collaborative Ethnography* https://disaster-sts-network.org/content/downstream-operations

Executive Yuan Press and Communication Department, "Fully promote offshore wind power - build Taiwan into an Asian offshore wind power technology industry cluster", contributed by Rex Simmons, *Project: Plastic Entwined, Disaster STS Network, Platform for Experimental Collaborative Ethnography* https://disaster-sts-network.org/content/fully-promote-offshore-wind-power-build-taiwan-asian-offshore-wind-power-technology-industry

Formosa Plastics Corporation, "2023 First Quarter Operations Performance Summary", contributed by Rex Simmons, *Project: Plastic Entwined, Disaster STS Network, Platform for Experimental Collaborative Ethnography* https://disaster-sts-network.org/content/2023-firs-quarter-operations-performance-summary

Formosa Plastics Group, "台塑企業達到碳中和之因應策略 Formosa Plastics Net Zero Strategies", contributed by Tim Schütz, *Project: Formosa Plastics Global Archive, Disaster STS Network, Platform for Experimental Collaborative Ethnography*. https://disaster-sts-network.org/content/台塑企業達到碳中和之因應策略-formosa-plastics-net-zero-strategies

Formosa Plastics Group, "Introduction to Formosa Automobile Corporation", contributed by Rex Simmons, *Project: Plastic Entwined, Disaster STS Network, Platform for Experimental Collaborative Ethnography*, https://disaster-sts-network.org/content/introduction-formosa-automobile-corporation

Formosa Plastics Group, "Formosa Lithium Iron Oxide Company", contributed by Rex Simmons, *Project: Plastic Entwined, Disaster STS Network, Platform for Experimental Collaborative Ethnography*, https://disaster-sts-network.org/content/formosa-lithium-iron-oxide-company

Formosa Plastics Group, "Nanya Photonics Flyer", contributed by Rex Simmons, *Project: Plastic Entwined, Disaster STS Network, Platform for Experimental Collaborative Ethnography*, https://disaster-sts-network.org/content/nanya-photovoltaics-flyer

Formosa Plastics Group, "Formosa Smart Tech Company Energy Storage Solutions", contributed by Rex Simmons, *Project: Plastic Entwined, Disaster STS Network, Platform for Experimental Collaborative Ethnography*, https://disaster-sts-network.org/content/formosa-smart-tech-company-energy-storage-solutions

Formosa Plastics Group, "FPG Tairylan Division - Tairyfil Data Sheet", contributed by Rex Simmons, *Project: Plastic Entwined, Disaster STS Network, Platform for Experimental Collaborative Ethnography* https://disaster-sts-network.org/content/fpg-tairylan-division-tairyfil-data-sheet

Formosa Plastics Group, "Formosa Dye Sensitized Solar Cells Flyer", contributed by Rex Simmons, *Project: Plastic Entwined, Disaster STS Network, Platform for Experimental Collaborative Ethnography* https://disaster-sts-network.org/content/formosa-dye-sensitized-solar-cells-flyer

Jacoby, Neil H. "An Evaluation of U.S. Economic Aid to Free China, 1951-1965", contributed by Rex Simmons, *Project: Plastic Entwined, Disaster STS Network, Platform for Experimental Collaborative Ethnography* https://disaster-sts-network.org/content/evaluation-us-economic-aid-free-china-195101965

Ministry of Economic Affairs, " Department of Industrial Technology - Performance evaluation of the Innovation Foresight Project", contributed by Rex Simmons, *Project: Plastic Entwined, Disaster STS Network, Platform for Experimental Collaborative Ethnography* https://disaster-sts-network.org/content/department-industrial-technology-performance-evaluation-innovation-foresight-project

Swancor Renewables, "Swancor Annual Report 2020", contributed by Rex Simmons, *Project: Plastic Entwined, Disaster STS Network, Platform for Experimental Collaborative Ethnography* https://disaster-sts-network.org/content/swancor-annual-report-2020

Wang, Qi and Taiwan Panorama, "The Acrylonitrile Plant of CPDC - A new force in development of Synthetic fibers", contributed by Rex Simmons, *Project: Plastic Entwined, Disaster STS Network, Platform for Experimental Collaborative Ethnography* https://disaster-sts-network.org/content/acrylonitril-plant-cpdc-new-force-development-synthetic-fibers

Wang Yufeng, "Old Bay, New Port - Excerpt", contributed by Rex Simmons, *Project: Plastic Entwined, Disaster STS Network, Platform for Experimental Collaborative Ethnography*, https://disaster-sts-network.org/content/old-bay-new-port-excerpt

The Asthma Files

The Plastform for Experimental Collaborative Ethnography also supports the Asthma Files, an archival effort to document air pollution in Kaohsiung. Access the archive here: https://theasthmafiles.org/

Historical Documents

Chapter one examined transcripts and documents relating to the US federal government and foreign affairs from 1945-1950. The documents listed below, and many others, are available at digital.library.wisc.edu under "Papers relating to the Foreign Relations of the United States."

"Interest of the United States in Fair Competitive Opportunity for American Oil Companies in China in View of Establishment of Chinese Government-Owned Oil Company" Oil. *Foreign Relations of the United States, 1946. The Far East: China*, Volume X. 1974.

"Problems of United States Consulates in areas Occupied by Chinese Communists" *Foreign relations of the United States, 1949. The Far East: China*, Volume VIII, 1978.

"The China Area" *Foreign relations of the United States, 1950. East Asia and the Pacific*, Volume VI, 1950.

List of Acronyms and Place Names

Acronyms

ABS - acrylic-butadiene-styrene
Adnoc - Abu Dhabi National Oil Company
AN - Acrylonitrile
BPA - Bisphenol A
BTX - Benzene Touline, and Xylene
COP 28 - United Nations Conference of the Parties 2023
CID - Center for Innovative Democracy
CCP - Chinese Communist Party

CPC - Chinese Petroleum Corporation, Taiwan
CPDC - China Petrochemical Development Corporation
DRAM - Dynamic Random Access Memory
DFI - Direct Foreign Investment
ECA - US Economic Cooperation Administration
EPA - US Environmental Protection Agency
EPZ - Economic Processing Zones
FPC - Formosa Plastics Corporation
FPG - Formosa Plastics Group[244]
GHG - Greenhouse gas
GWh - Gigawatt hour
IEA - International Energy Agency
INC - International Negotiating Committee
ITRI - Industrial Technology Research Institute
KMT - Kuomintang, the former martial law government and a contemporary political party in Taiwan
KWh - Kilowatt hour
LNG - Liquified Natural Gas
MOEA - Ministry of Economic Affairs
MRL - Materials Research Laborotores
MWh - Megawatt hour
NTD - New Taiwan Dollar
OPEC - Organization of Petroleum Exporting Countries
PTA - Pure Terephthalic Acid
PV - Photovoltaic
PVC - Polyvinyl Chloride
SABIC - Saudi Basic Industries Company
SCCT - Swedish Chamber of Commerce in Taipei
SRF - Solid Recovered Fuels for power generated by trash combustion
TSMC - Taiwan Semiconductor Manufacturing Company
UAE - United Arab Emirates
US - United States
USD - United States Dollar

[244] This term is used to refer to the petrochemical conglomerate as a whole, interchangeably with “Formosa” and “Formosa Plastics”

VCM - Vinyl Chloride Monomer
VOC - Volatile Organic Compound

<u>Place Names</u>

Changhua 彰化 - A county in Taiwan, where the Changbin industrial park is located
Changbin 長濱 - An artificial industrial park on the coast of Ch
Dashe 大社 - A neighborhood and major petrochemical processing zone in Kaohsiung
Dalinpu 大林蒲 - A neighborhood near the Dalin refinery and Kaohsiung port
Kaohsiung 高雄 - A mid-sized to large city on the Southwestern coast of Taiwan
Liuqing 六輕- the Formosa Plastics Sixth Naphtha Cracker, located in Mailiao, Yunlin, Taiwan
Lukang 鹿港 - A town in Changhua County, Taiwan
Mailiao 麥寮 - A town in Yunlin County, Taiwan, where Liuqing is located
Renwu 仁武 - A neighborhood in and a major petrochemical processing zone Kaohsiung,
Siaogang 小港 - A neighborhood near the Dalin refinery and Kaohsiung port
Taichung 台中 - A city and county in central Taiwan, and the location of a major port
Wuqing 五輕 - The CPC Fifth Naphtha Cracker, located in Kaohsiung
Yunlin 雲林- A county in Southwest Taiwan

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