From Carbon to Human Health: Lifecycle of Fossil Fuels, Toxic Polymers and Social Justice in Philadelphia

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The ubiquitous use of plastics in architectural design and construction obfuscates the very real human health risks which exist when polymers—derived from petroleum, coal, or natural gas—are used in the building industry. For more than fifty years, a majority of construction materials have been engineered using polymers for the purposes of achieving a range of advanced performance capacities. These materials are widely manipulated using fossil fuel derivatives for augmenting their structural strength, moisture resistance, form finding, or general resistance to weathering. Polyvinyl chlorides, for example, are used in plumbing supplies, exterior sheathing, interior surfaces, furniture, and landscaping, for these reasons. Indeed, nearly everything in our built environment is permeated by chemicals derived from fossil fuels. This is obviously problematic for carbon emissions: it is all the more critical in what concerns human health. More than half a century following the deliberate and orchestrated flooding of the construction market with inexpensive plastics, very little data is disclosed about the potential health risks associated with adopting such large quantities of nonrenewable, nonrecyclable, and wasteful materials. Architects, engineers, builders, clients, and the general public are poorly informed on the toxic accumulation of highly synthetic building polymers that originate in carbon intensive fossil fuel industries and that saturate our air, water, and physical bodies. In response, this paper reports on the results of a funded research project aimed at identifying the sources, risks, and impacts of using such materials in the building industry. Funded by the Kleinman Center and the Penn Undergraduate Research Mentoring program at the University of Pennsylvania, the project studies site-specific material flows involved in the lifecycle of a set of polymers manufactured in the Philadelphia region. Invisible to most, yet present in many communities, are industrial sites which distill, manufacture, and fabricate the polymerized materials that pose the highest risks when building. This has been the case in the city of Philadelphia where for decades fossil fuels and their derivatives intended for the building industry have been manipulated, with risk. Sharing evidence of this, is the focus of this paper.

PLASTICS AND SOCIAL JUSTICE

The ubiquitous use of plastics in architectural design and construction is an issue that impacts the entire life cycle of polymers; yet polymers inflict significant trauma on human health most acutely at the beginning and end of life. The larger research to which this paper speaks to is comprised of three parts; the first speaks to the uncritical and boundless use of polymers in the building industry and the carbon costs of doing so;[1] the second addresses the need for greater transparency in accounting for toxins to which we are exposed in buildings;[2] the third reminds us that at birth and death, polymers are the most dangerous to human health, and this unevenly in society. As with many socially determined constructs, polymers impact populations disproportionately. Zip codes in the United States are the prime determinants of wealth, health, and death; and this, no truer than in the case of plastics whose most egregious harms are levied against the economically dispossessed and communities of colors. Given the limitation of any one paper, and the larger social and political context of Fall 2020 in the United States, this paper is focused on the third and final part – social justice and building polymers.

POLYMERS NEVER DIE

At their origins, polymers have already outlived us, and as waste they outlive us, once again. To understand this issue, let us return to beginnings, that is to the material beginnings of polymers. In this, we must confront their volatile origins lest we forget that the great majority of plastics in the building industry originate in highly explosive natural gas or crude oil.[3] Even if according to the U.S. Energy Information Administration, they are "unable to determine the specific amounts or origin of the feedstocks that are actually used to manufacture plastics in the United States,"[4] there is no denying it—polymers are born of danger.

EXPLOSION 1: LAC MEGANTIC, QUEBEC

In the early hours of the morning of July 5th, 2013, in Lac Megantic—a small town of 6000 inhabitants in the eastern townships of the province of Quebec—a train derailment and explosion resulted in the death of 47 local inhabitants. The train of 74 cars was carrying two million gallons of crude oil when it was left on a hill without the proper securing of its break. At 1:00 am in the dead of night the train barreled without conductor on a Friday evening towards the town center travelling at 65 miles per hour. As it hit the 10 miles per hour curve at the head of Lac Megantic, it derailed igniting the town center and its local bar, filled with locals. The explosion,

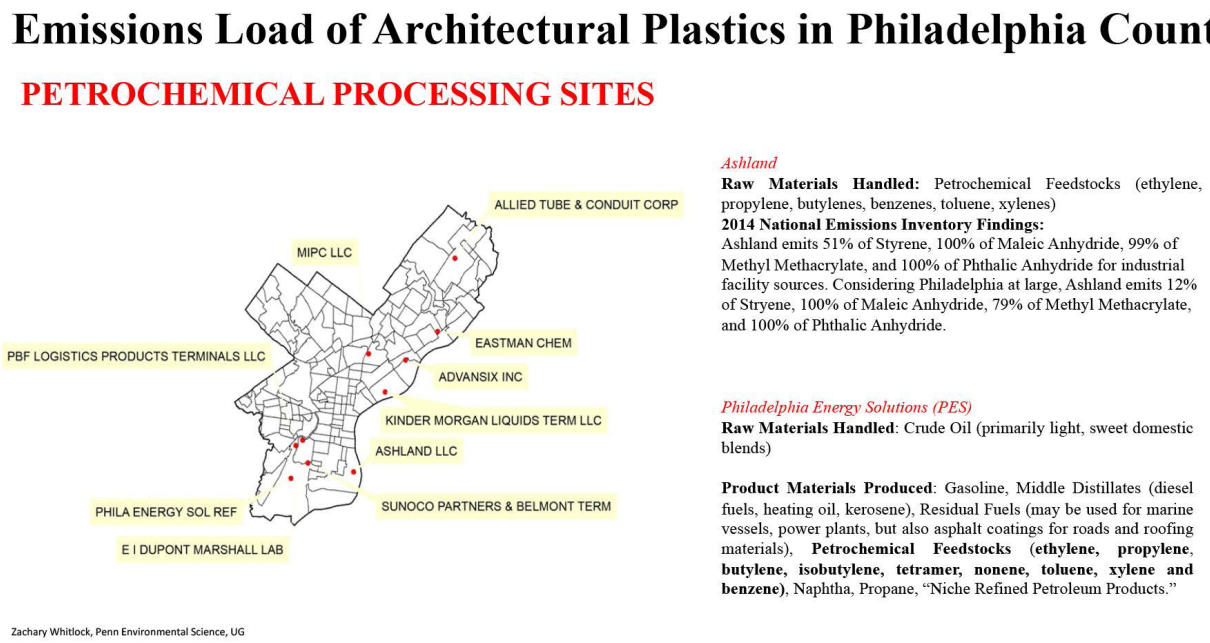

Figure 1: Emissions Load of Architectural Plastics in Philadelphia County, Petrochemical Processing Sites

fire, and petroleum contamination destroyed thirty buildings, more than half of the town and its history.[5] It also resulted in 100,000 liters of crude oil being spilled into the Chaudière River.[6] The oil, on its way to the Irving Oil Refinery in Saint John New Brunswick, was shipped nearly two thousand miles from North Dakota. It originated from deep within the ground in the Bakken Oil Formation.[7] The oil was made to travel across a province that boasts the largest hydro-electric facility in Canada, with Hydro Quebec being the fourth largest world-wide producer of water based renewable energy.

EXPLOSION 2: PHILADELPHIA, PA

The date was June 21st, 2019. It was almost daybreak. The sun had not yet started to rise over the city of Philadelphia. It was going to be a special day. It was summer solstice. The one day of the year when the sun has its longest performance, its pride of place, and we celebrate its life sustaining presence—its warmth, light rays, and energy. And yet, it was the "sun" of a different kind that awoke the good citizens of Philadelphia on that fated morning. A fire ball exploded just after 4:00 am at the oil refinery located in the southwest corner of Center City and managed by Philadelphia Energy Solutions (PES), the largest petroleum refinery in the Northeast.[8] The explosion sent into the sky plums of toxic chemicals, smoke, particles, and deadly projectiles. The explosion torched the contents of a storage tank in an alkylation unit that used highly volatile hydrofluoric acid. The cause it was assumed was a corroded pipe elbow in the unit that had leaked. The acid leaked through the corroded pipe, forming a vapor cloud which quickly ignited.[9] Hydrofluoric acid is a highly caustic chemical that must be handled with great caution.[10] Within minutes, multiple explosions ensued.[11] The third explosion was the most powerful; it hurled a 38,000lb chunk of debris across the Schuylkill River to the west of the site, while two other pieces weighing 23,000lbs and 15,500lbs respectively landed within the PES site.[12] The fire in the alkylation unit burned for twenty-four hours until it was extinguished at 8AM on June 22.[13] The process of neutralizing the Hydrofluoric acid took nearly a month. A truly cataclysmic disaster was narrowly avoided due to the very quick thinking of "control room operator, Barbara McHugh" who in the early hours of the morning had the courage to act quickly," taking the necessary steps to drain the hydrofluoric acid into a special emergency holding tank.[14] And yet, for the citizens of Philadelphia and those living immediately to the east of the refinery in zip code 19145, propane and butane burned for hours.

Was this of concern to Philadelphia Energy Solutions (PES) who managed the oil refining complex? PES purchased the site and its operations from Sunoco (a petroleum company creatively branded as the Sun-oil-company) in the summer of 2012.[15] Given the site's poor maintenance one would not think so: the fire and explosion only confirmed the refinery's destiny to close. Post-accident investigations by the Chemical Safety Board revealed that the ruptured elbow which was the cause of the explosion was "0.012 in. thick, less than a tenth of the

Emissions Load of Architectural Plastics in Philadelphia County

RISKS

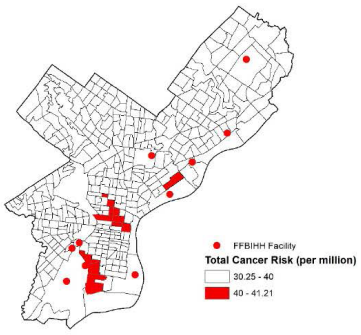

Figure 1: National Air Toxics Assessment 2014 cancer risk over Philadelphia census tracts
Zachary Whitlock, Penn Environmental Science, UG

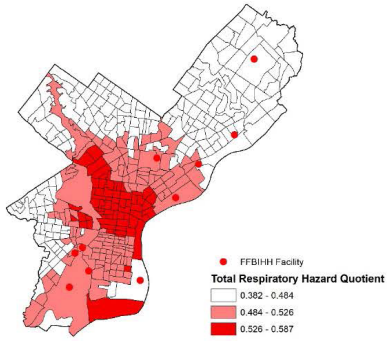

Figure 2: National Air Toxics Assessment 2014 respiratory hazard over Philadelphia census tracts
Zachary Whitlock, Penn Environmental Science, UG

Figure 2: Emissions Load of Architectural Plastics in Philadelphia County, Risks

thickness that would have triggered a replacement."[16] It being noted by John Jechura, professor of practice at the Colorado School of Mines, that "the areas most vulnerable to corrosion — and thus potential cracks and leaks — are places in the pipe where there is a change in the flow direction: T's, Y's, and elbows," might one ask about possible professional and corporate negligence?[17] Before its stated bankruptcy in 2018, PES was 65% majority owned by the Carlyle Group, a private equity fund in the business of liquidating unprofitable businesses.[18]

THE RISKS AND PRODUCTS OF REFINING

Refining operations in southwest Philadelphia were nothing new. Early forms of refining have taken place at this location for close to 160 years, having begun at the end of the Civil War.[19] Before its closure, it was the biggest refining site for crude oil in the Northeast of the United States. When it closed its doors for good within months of the explosion, it employed 1,100 employees, of which roughly 650 were unionized with the United Steel Workers.[20]

PES produced a host of refining products; gasoline, diesel fuels, heating fuels, kerosene, propane, and petrochemical feedstocks.[21] Of most interest to architects, petroleum feedstocks are the waste resulting from the refining process—essentially the free fuel that feeds the industry's desire for more and more plastics—that includes ethylene, propylene, butylene, isobutylene, tetramer, nonene, toluene, xylene, and benzene.

Following its purchase of the site, PES sourced part of its domestic oil from North Dakota's Bakken formation, located more than 1500 miles away. The Bakken Formation straddles two states and two Canadian provinces—North Dakota, Montana, Manitoba and Saskatchewan. According to Reuters, at its peak in 2013-2015, PES imported three trains of Bakken oil per day, for a total of over 200,000 barrels.[22] It even built a rail terminal to receive these shipments from North Dakota during the Bakken oil boom.[23]

Some of the most productive areas for extraction of Bakken oil in North Dakota lie beneath the Fort Berthold reservation, which is home to the Mandan, Hidatsa, and Arikara (MHA) nation.[24] According to reporting by the Public Broadcasting Society (PBS) in their episode "Native American Boomtown" in the series Americans by the Numbers, initially MHA nation members benefitted from the oil extraction. They were compensated financially for the right to drill under their lands.[25] The transaction was consensual, and the 3,500 companies working on the reservation hired tribe members for at least 50% of the skilled jobs.[26] Contractually it may have been a fair agreement. However, without delay, the Bakken oil boom brought organized crime, human trafficking, and drugs; all of which contributed to undermining the first nation's health and sense of community.[27] With the coming of oil, the community experienced outsized exchanges of money, excessive charges for housing and basic services, and drug related activities grew two-fold on the reservation.[28] Environmentally, the North Dakota oil boom has been no less devastating. According to the already cited "Native American Boomtown" by 2014, "over one million gallons of fracking water spilled over a tributary of lake Sakakawea, which threatens tribal drinking water."[29] Despite concerns expressed by community members, the tribal government maintained that the drinking water was safe, and that remediation was underway.[30] According to "Circle of Blue", a nonprofit focused on issues of water scarcity,

"Oil and gas production from the Bakken Shale is projected to use up to 5.5 billion gallons of water annually for as many as two decades."[31]

It is all the more tragic that so much of the oil is being wasted by way of flaring. As recorded by the NASA Goddard Space Flight Center:

> *According to the U.S. Energy Information Administration, natural gas production from the Bakken shale has increased more than 20-fold between 2007 and 2010. Companies hoping to extract oil from the Bakken formation have drilled hundreds of new wells in the last few years; natural gas often bubbles up to the surface as part of the process. Lacking the infrastructure to pipe the gas away, many drillers simply burn it in a practice known as flaring. Due to the lack of gas pipeline and processing facilities in the region, about 29 percent of that gas is flared.*[32]

And, if this were not enough, with the arrival of oil and gas, by 2013 North Dakota had become the most dangerous US state to work in, with nearly fifteen workers per 100,000 perishing at work: this being more than four times the national rate.[33] Hence, in so many ways, at the beginning of their lives in fossil fuels, polymers and their allied industries kill.

ACKNOWLEDGING THE RISK TO FENCE LINE COMMUNITIES

Thankfully, only five injuries were recorded as a direct result of the explosion, even as nearly 400,000 people live within a 2.5-mile radius of the refinery.[34] On a daily basis, railcars delivering crude oil to the PES site traveled immediately adjacent to some of the densest residential and recreational sites in Center City Philadelphia within feet of dog parks, basketball courts, community gardens, the Philadelphia region commuter and Amtrak station, and the city's main post-office. According to City of Philadelphia officials, the explosion posed no serious threat to the surrounding community, as "no ambient carbon monoxide, hydrocarbons (combustibles), or hydrogen sulfide," were measured by the "Philadelphia Department of Public Health."[35]

Living immediately to the north of the site, less than 2 miles away, I was shaken out of bed. I was not reassured when being told to shelter in place. We have since come to know that the explosion released 676,000 pounds of hydrocarbons, most of which burned in the fire and explosion and hence, was transported through the air.[36] In addition, according to a report released in October 2019, by the US Chemical Safety and Hazard Investigation Board, "3,271 pounds of the dangerous hydrofluoric acid was released into the atmosphere, while the refinery's water spray system contained about 1,968 pounds of HF."[37] Even in small quantities, hydrofluoric acid in contact with the skin is deadly. And when delivered as a gas, it can cause eye and nose irritation. When one breathes hydrofluoric acid, it can kill.[38]

This was truly an exceptional day. However, the PES site has posed risks to the city of Philadelphia for nearly a hundred years, and certainly in the years just prior to its closure. The environmental health of the site being an interest of Professor Peter DeCarlo, Atmospheric Scientist from John Hopkins University, who has studied this site for years and modeled the air plum trajectories which were registered on June 21st, 2019, given prevailing winds. And as identified in an article by EE News, "In December 2019, the data shows, the refinery's average annual benzene emissions level was 49 micrograms per cubic meter of air — more than five times the EPA limit."[39]

Fence line communities have known this for decades. We simply need to ask the residents. Ask Zalaka Thompson, for example, who as a resident of Grays Ferry—the fence-line community to immediate east and north of the refinery—notes how, "her 14-year old son has asthma and carries an inhaler with him at all times, on the doctor's orders. And some mornings, she can't keep her windows open for long without smelling gas or sulfur."[40] While resident Sonya Sanders, member of Philly Thrive and resident of the Grays Ferry community observes, "We've all been living here since we were kids. OK, this has been going on since our mothers were children. This has to stop."[41] And Kilynn Johnson confirms that, "We smell [foul odors from the refinery] like it's in our house. I have to go get blankets, put it down by the door, make sure my windows are shut … we are scared to death.[42]

Community activists with Philly Thrive, The Asthma Files, ACTION United, 350.org Philadelphia, and the Earth Quaker Action Team (EQAT) who have all been involved with the site. Ask Russell Zerbo, Advocate from the Clean Air Council, a local Philadelphia non-profit that sued PES in 2012.[43] Ask Dr. Marilyn Howarth, occupational and environmental medicine physician from the Center for Excellence in Environmental Toxicology at the University of Pennsylvania, who has worked with front line communities sharing with them the cumulative effects of living in such close proximity to environmental pollutants. And ask Bilal Motley, the engineer who worked at the PES refinery and whose 40-minute documentary Midnight Oil recounts episodes and sentiments associated with the last days of the refinery before its closing. Amongst his admissions in the documentary Mr. Motley noted: "We put oil in the river many, many times."[44]

Indeed, it should be no surprise that environmental and health traumas were nothing new at PES. An NBC news report from May 2019, one month before the disaster, noted that levels of benzene in the air adjacent to the refinery were over twenty-one times the EPA's maximum allowable amount.[45] Since 2003, the EPA had also known of excessive levels of "Light non aqueous phase liquid (LNAPL) pollution in the refinery's

groundwater, which contains dissolved benzene, toluene, ethylbenzene and xylene."[46] In 2001 tests for non-drinking water aquifers, the refinery's groundwater exceeds the State of Pennsylvania's health standards for benzene, polycyclic aromatic hydrocarbons (PAHs), and other chemicals.[47]

Environmental violations at the PES site were commonplace. The site and its operations were found to violate the Clean Water Act, the Clean Air Act, and the Safe Drinking Water Act.[48] According to the EPA ECHO report for the PES/Schuylkill Tank Farm, it violated the Clean Air Act with high priority violations during 2018 and 2019, for pollutants that include are Carbon Monoxide CO, Ammonia, Volitive Organic Compounds VOCs, Hydrogen sulfide, Nitrogen Oxides, Sulphur Oxide, and noxious odors.[49] It violated the Clean Water Act at two discharge points and for its discharge of carbonaceous BOD, fluoride, oil and grease, suspended solids, and sulfides.[50] Indeed, violations of the Clean Air Act and Clean Water Act resulted in Federal and State penalties summing $832,975 over the last five years.[51]

These violations are not benign: they have consequences. Based on the Philly Thrive, "#WeDecide Our Energy Future, Survey Report," 33.9% of fence line residents experience asthma, while the national average is 7.7 %; 21.1% of fence line residents experience other respiratory conditions; 16.4% of fence line residents experience heart disease; 7% of fence line residents succumb to cancer; [52].6% of fence line residents experience one of these conditions; and of all residents who are 61 and older, 69.6% have experienced one or more of the four health conditions.52 Based on the "Clean Air Council Sunoco Refinery Remediation, Primer for Action," pollutants of concern at the PES Site include lead as a heavy metal "that can bio-accumulate in the body, Benzene that is a hydrocarbon and human carcinogen, Methyl tert-butyl ether (MTBE) that is a gasoline additive, and NAPLs - non-aqueous phase liquids, that are Light non-aqueous phase liquids (LNAPL) whose groundwater contaminants settle at the top of the water table – such as gasoline, benzene, toluene, and Dense non-aqueous phase liquids (DNAPL) whose contaminants include extra heavy crude oil, coal tar, PCBs, creosote."[53]

ACKNOWLEDGING THE RESIDENTS OF PES' FENCE LINE COMMUNITIES

According to the EPA's Environmental Justice Screen, census data for zip code 19145 reveals that the majority of residents who live immediately to the east of the site identify as communities of color (Black and Asian) and 45% of the population are identified as Low-Income residents.[54] The Unemployment rate in 19145 was 11%, prior to the Covid pandemic, which was twice the State rate. And in what concerns the building infrastructure, twice as many as homes were built before 1939 than throughout the State of Pennsylvania, with the added risks of lead poisoning. According to the EPA's Environment Justice Screen, the population of 19145 scores more poorly than the national average in all key markers including Diesel Exposure – 100% more, Cancer Risk – 40 % more, Lead Paint Indicator – 300% more, Hazardous Waste Proximity –100% more, Superfund Proximity – 100% more, and Wastewater Discharge (toxicity) – 1000 % more. For decades, children of color and low-income children in the city of Philadelphia have struggled with their respiratory health and with attaining educational benchmarks. Should we be surprised given the environmental conditions they are subjected to?

To be clear, Philadelphians were subject to environmental risks at the PES refinery. With its closure, this does not mean that they are free from chemical contaminants. An additional number of petrochemical processing sites are located along its Northeast boundary. Amongst which are Ashland Chemical whose plant produces cement, adhesives, window films, architectural paints, finishes, and stains.[55] They ship their products to 100 different countries. Honeywell Frankford Advansix produces phenol, acetone, and alpha-methylstyrene.[56] Most of the phenol produced (80%) is shipped to AdvanSix's Hopewell, VA plant to produce caprolactam,[57] the main feedstock for Nylon, which is used throughout the architectural industry in carpets and other fabric wares. All of whom variously release toxic emissions including Ashland Chemical's emissions of Stryene, Maleic Anhydride, Methyl Methacrylate, and Phthalic Anhydride. Not surprisingly, Honeywell Frankford (AdvanSix) has violated the Clean Air Act and the Clean Water Act.[58] They've had two nonconsecutive Clean Air Act violations in the last three years.[59] They also have a spotted record with compliance of the Clean Water Act.[60]

CONCLUSION – ARE WE ALL COMPLICIT?

In the hours before the break of dawn, on June 21st, 2019, when we were being told to shelter in place as the refinery was exploding and emitting hydrofluoric acid in the air that Philadelphians breath, I had no idea that I was living in a fence-line community of a major petrol-chemical plant and the tragedy was, in part, of my own doing. As an architect and educator, I too was complicit in drumming up interest in materials that first see the light of day in the refining of petrochemicals and whose feed stocks deliver ethylene, propylene, butylene, isobutylene, tetramer, nonene, toluene, xylene, and benzene. These are the favored building blocks of all of our favorite plastics, and it is no secret that many of us love plastics. Indeed, the industry is addicted to them!

And hence, in this case as in others, let us begin by looking in our own backyards for solutions to this life and death problem. The time is now to stop looking away, and to stop avoiding the fact that many of the material choices we make, are killing us. On that fated morning of Solstice 2019, I was sleeping under my roof of solar panels. That day, the longest of the solar calendar, I produced more solar power than on any other day of the year. Philadelphia has, thankfully, become a hub of renewable energy in the Northeast. New solar projects, big and small, are being installed at a rapid rate. Contrary to the

ball of fire with which I began this presentation, the closing of Philadelphia Energy Solutions, portends a new world, one where fossil fuels are left in the ground and plastics are consumed with much moderation.

ACKNOWLEDGMENTS

I am appreciative of the research work undertaken by undergraduate students at the University of Pennsylvania, Zachary Whitlock, Sage Basri and Kai Song, in support of this paper.

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