Oswald Jenewein

Post-Oil Environments

Developing a Typological Approach to Climate Adaptation of Architecture and the City

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Developing a Typological Approach to Climate Adaptation of Architecture and the City

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Contents

The burning of fossil fuels has been a driver of global warming. Now, temperatures are increasing, creating a vertical problem for the built environment, as the shifting edges between water and land destabilize the very foundation of architecture and the city: the ground.

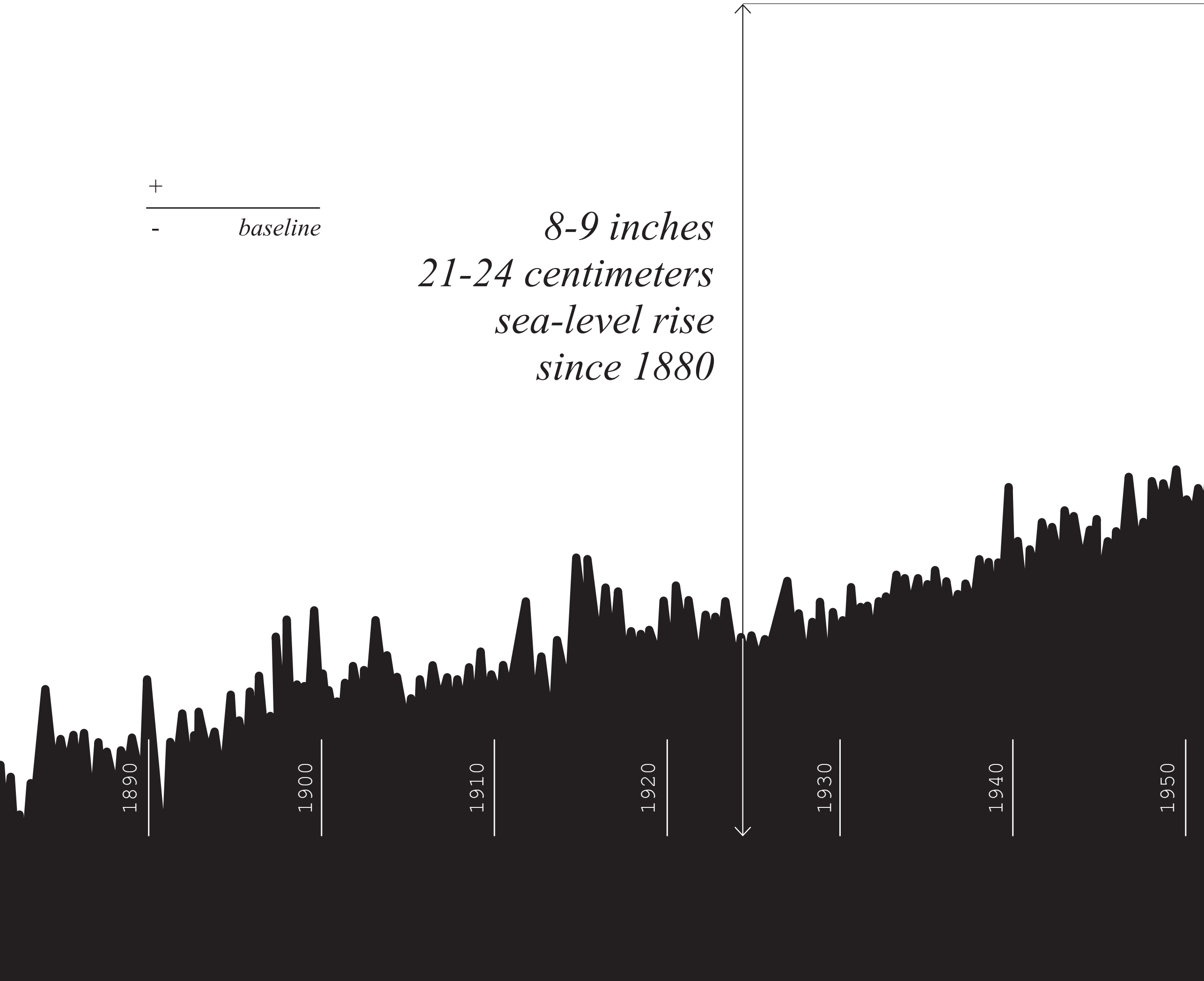
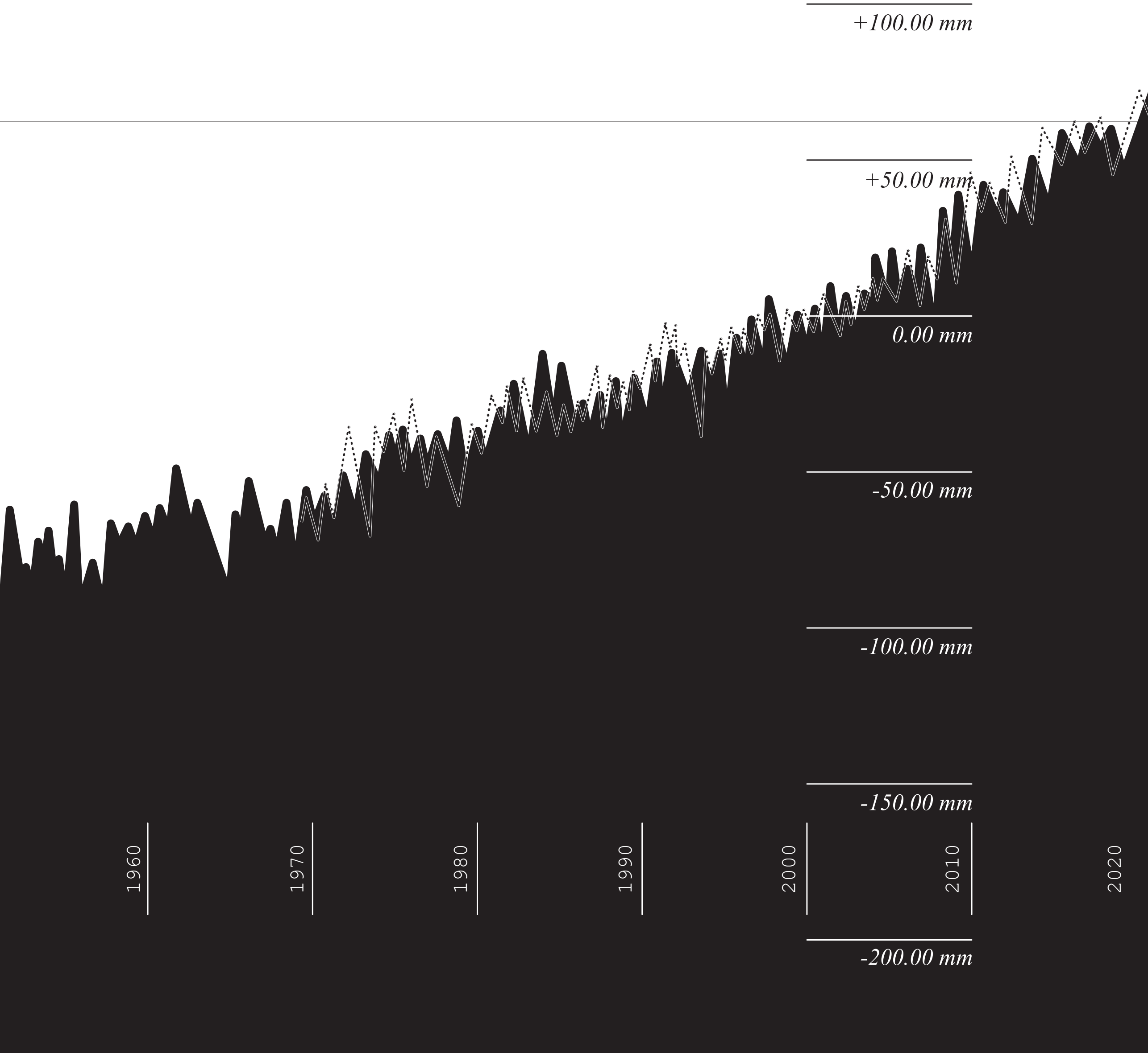


Figure 1. Sea-level rise since 1880, showing the global mean water level. The sea-level rose between 21-24 centimeters or 8-9 inches. (Data extracted from NOAA, "Climate Change Impacts.")



01

Introduction

00

Introduction

SCOPE

The physical repercussions of anthropogenic climate change are impacting the natural, cultural, and built environment at an unprecedented pace and scale. Especially, coastal cities experience environmental challenges due to their fragile urban ecosystems located in vulnerable geographic locations. This book addresses climate adaptation of architecture and the city, focusing on two crucial design principles: context and form. Situated at the convergence of architecture and landscape architecture, the primary question asks how architecture can develop a disciplinary response to climate change by addressing this topic as a vertical problem. First, this work summarizes the historical developments that transformed the burning of fossil fuels into a spatial regime, leading to the current stage of environmental crisis. Second, the Texas Coast has been chosen as a geopolitical territory to define unique urban typologies, showcasing the spatial correlation between fossil fuels and the origins, drivers, and impacts of global warming in the city. Third, typological adaptation is proposed as a method to develop climate adaptation strategies of the built environment, investigating the sectional relationship between the architectural object and its ground. Lastly, this work concludes in outlining how a typological approach could be utilized as a disciplinary response to climate adaptation of architecture and the city in a post-oil environment.

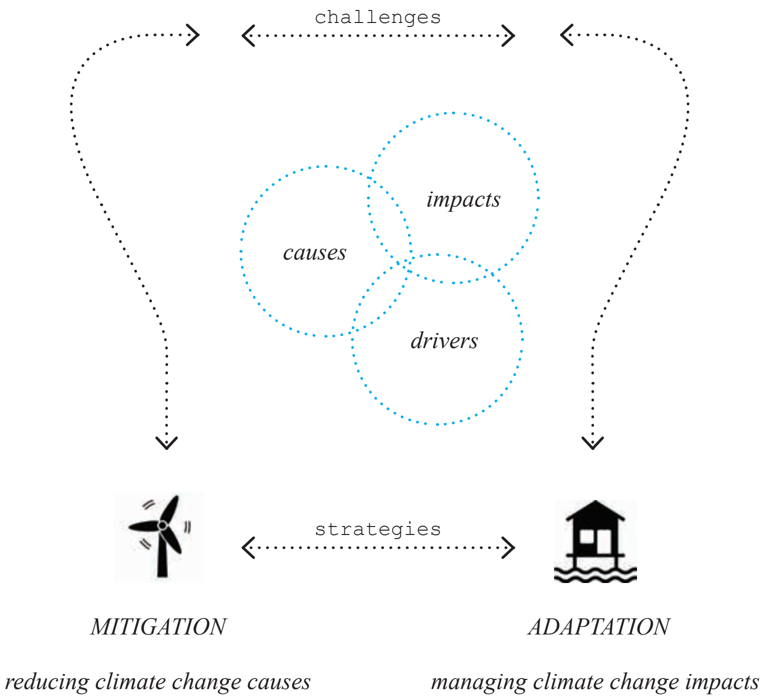


Figure 2. Overview of climate change causes, drivers, and impacts, and two major strategies to respond: mitigation and adaptation. (Content appropriated from NASA, "Responding to Climate Change")

1.a.
BACKGROUND & DISCIPLINARY REMARKS

Climate change is a global challenge that requires a collective response. Addressing this planetary crisis demands responses across different scales, from geopolitical decisions to regional and urban frameworks, and even to behavioral actions of individuals.[1, 2] The key factors contributing to the climate crisis can be divided into causes, drivers, and impacts. This categorization enables a better understanding of the origins of the problem, the factors that increase and accelerate it, and the different outcomes that materialize and impact the natural and built environment. Architecture, as a critical component of the urban ecosystem, can be seen as a cause, driver, or impact of climate change.[3] This is especially true since architecture serves as the physical background for everyday life, making it a breeding ground for environmental pollution. However, the burning of fossil fuels is the biggest source of global warming, leading to a rise in temperatures. The anthropogenic release of hydrocarbons into the atmosphere and the associated warming trends cause various environmental impacts: rising water levels are one of them.[4] These processes have started to shift the edges between water and land, destabilizing the physical premise for architecture and the city: the ground. As reference surfaces, water and land vertically relate the architectural object to its environment. Hence, out of the many climate change impacts, flooding represents an inherently contextual and formal problem for the architecture of the city, affecting the sectional relationship between object and ground, building and terrain, or city and landscape.[5]

1 Cf. Condon, Cavens, and Miller, Urban Planning Tools for Climate Change Mitigation.
2 Cf. Stone, Vargo, and Habeeb, “Managing Climate Change in Cities: Will Climate Action Plans Work?”
3 Cf. Jenewein and Hummel, “Co-Creating Climate Adaptation Pathways in Coastal Cities: A Practical Guide for Engaged Scholars and Urban Designers.”
4 See EPA, “Sources of Greenhouse Gas Emissions”
5 The idea of investigating climate change impacts vertically builds on a special issue of ARCH+, edited by Aus dem Moore et al., “Post-Oil City. The History of the City’s Future.”

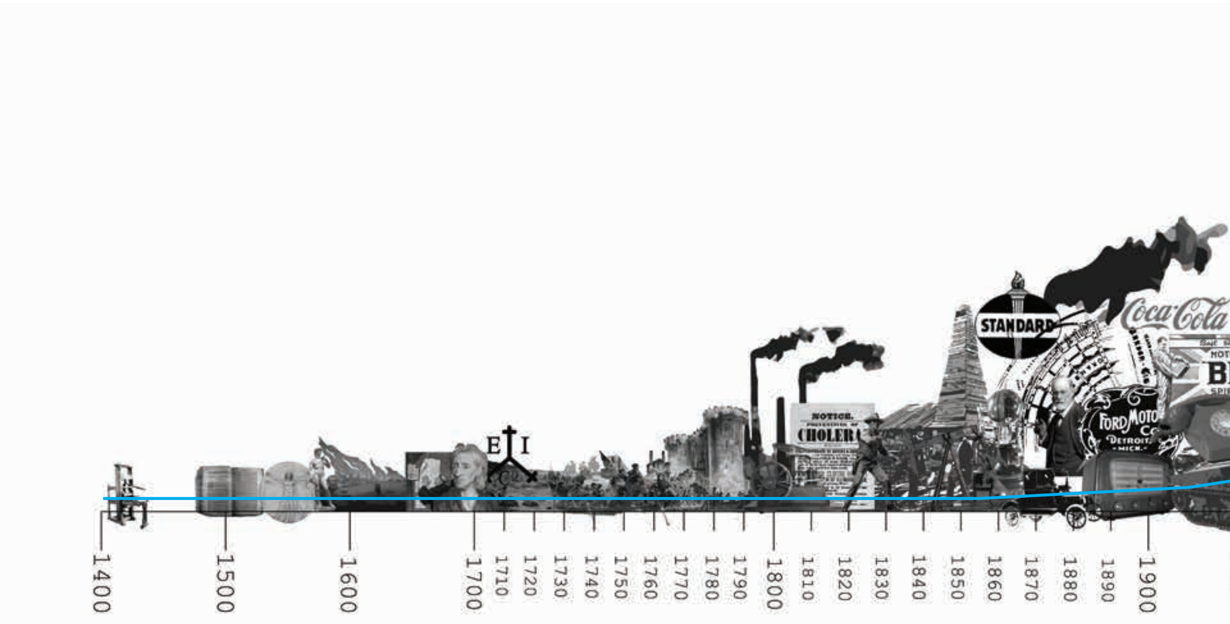


Figure 3. Timeline of events enabling fossil fuels as a spatial regime, from the invention the printing press to mass-producing books, across the Era of Enlightenment to the time of rapid growth in the various stages of the Industrial Revolution. Starting from the late 19th century, industrial production, powered by fossil fuels, has grown rapidly, enabling cities within an "Oil

Especially coastal cities are at the forefront of experiencing the repercussions of climate change, particularly flooding, as anthropogenic land use and industrial activity in coastal zones alter shorelines.[6] The dredging of ship channels and canals, for instance, might accelerate saltwater intrusion. With changing salinity levels in bays and estuaries along coastlines, entire coastal ecosystems are about to change.[7] This example of anthropogenic land-use highlights how human-caused vulnerability drivers may accelerate climate

6 Cf. Balica, Wright, and Van der Meulen, “A Flood Vulnerability Index for Coastal Cities and Its Use in Assessing Climate Change Impacts.”

7 Cf. Barlow and Reichard, “Saltwater Intrusion in Coastal Regions of North America.”

Environment." About 100 years later, as major organizations acknowledge the devastating environmental impacts of fossil-fuel-burning, cities have started to transition to a "Post-Oil Environment." (Appropriated from Jenewein, “The Frequency of (in-)Dependence: A Post-Oil Future in a Post-Pandemic World. Case-Study Texas Coast in the Time of COVID-19.” p. 119)

change impacts in coastal regions.[8] It also shows how the ground condition is a crucial component of the urban ecosystem and a potential threat to both natural and constructed elements of the city.

As humankind attempts to mitigate some of the most devastating environmental repercussions, cities need to adapt to change.[9] Mitigation as a concept to tackle the climate crisis focuses on the reduction of causes, like decreasing carbon emissions or utilizing clean energy sources. Adaptation,

8 Cf. Jenewein and Hummel, “Developing Climate Adaptation Pathways with Communities Impacted by Sea-Level Rise and Industrial Development.”

9 Cf. NASA, “Responding to Climate Change”

on the other hand, describes the process of adjusting to climate change impacts, like rising temperatures or sea-levels.[10] In the process of identifying adaptive strategies within the built environment, the origins and impacts of climate change should be considered as parameters with a direct spatial correlation. There are three primary adaptation options for human settlements according to the Intergovernmental Panel on Climate Change: (1) protect, (2) accommodate, (3) retreat, also called PAR.[11] These options were later expanded to include (4) avoid, known as PARA.[12] Yet, several concepts of climate adaptation have been labeled with similar intentions. Whether it is PAR, PARA or described as (1) adapt, (2) defend, or (3) retreat,[13] climate change responses should ideally be a combination of approaches spanning from avoiding causes to mitigating and adapting to impacts. Depending on the geographic location and the geologic formation of the respective coastal region, the orderly retreat from the coast might be the only long-term solution.[14] Yet, with regard to the communities populating coastal cities and harvesting the benefits of the diverse marine ecosystems, retreat from the coast should be a last resort. Defending the city against environmental impacts has historically been a common practice, especially in the 20th century when gigantic human-built structures made of steel or concrete were put in place to regulate nature. Describing the progress within the Industrial Revolution over time, the World Economic Forum describes the respective stages as (1) First Industrial Revolution using steam-power to mechanize, (2) Second Industrial Revolution using electric-power to mass-produce, (3) Third Industrial Revolution using electronics to automate, and (4) Fourth Industrial Revolution using technology to integrate physical, digital, and biological components in production processes.[15] Following the mindset of the Fourth Industrial Rev-

10 See UN, “Climate Adaptation.”
11 See WJ. McG. Tegart, G.W. Sheldon, “Climate Change. The IPCC Impacts Assessment.”
12 See Doberstein, Fitzgibbons, and Mitchell, “Protect, Accommodate, Retreat or Avoid (PARA): Canadian Community Options for Flood Disaster Risk Reduction and Flood Resilience.”
13 See Sinay and Carter, “Climate Change Adaptation Options for Coastal Communities and Local Governments.”
14 Cf. Haasnoot, Lawrence, and Magnan, “Pathways to Coastal Retreat.”
15 Referring to the definition of the "Fourth Industrial Revolution" as defined by the World Economic Forum, described by Schwab, The Fourth Industrial Revolution.

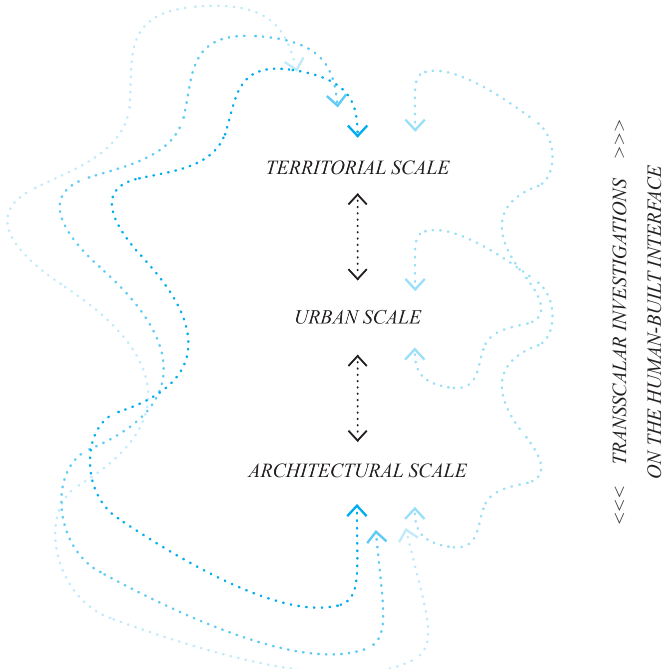


Figure 4. This work follows a transscalar approach, relating territorial, urban, and architectural scales to the human/built interface.

olution, combining physical, digital, and biological components to develop solutions suggests approaches working with and not against nature is the only possible solution in case of adaptation.

The climate crisis is a challenge of unprecedented scale and impact. Across many academic disciplines, researchers, scientists, and designers identify ecological problems and propose concepts of how humankind could overcome certain components of these problems within their respective fields. Architecture is neither a traditional science, nor simply part of the humanities, and more than just a field of arts, yet, to a degree, part of all academic branches.[16, 17] In regards to climate change, it is clear that the built environment and how we think and rethink buildings, cities, and the processes and systems

16 Cf. Ballantyne, "What Is Architecture?"
17 Cf. de Giorgi and Hoffmann, “What Is Architecture.”

within are key to creating the resilient environment desperately needed for the planet to recover from the impacts of anthropogenic carbon emissions spanning over more than two centuries. The solutions for more resilient buildings are often found in disciplines outside of architecture: engineers develop new materials, more efficient heating and cooling systems based on renewable energy, rain-water collectors, etc. However, architecture needs to develop a disciplinary identity and response to climate change to remain relevant in this most pressing crisis of our time.

Aiming to answer how architecture can develop a disciplinary response to climate change, this work utilizes a transscalar approach,[18] zooming from the territorial, across the urban, to the architectural scale. This method builds on the premise that ecological design requires a holistic understanding of the respective topic. This work also assumes that ecological approaches are inherently place-related. Therefore, the focus on a specific coastal region that is both prone to environmental and industrial impacts that cause and drive climate change is crucial. To link the causes, drivers, and impacts of climate change to the city utilizing a specific case study, this work describes the burning of fossil fuels as a spatial regime. On the following pages, spatial regimes are described as 'rules' that shape the natural, cultural, and built environment. This book investigates 'the burning of fossil fuels' as a particular spatial regime to demonstrate how human activity has shaped the natural environment, which forms the basis for architectural creation. After summarizing the historical relationship between fossil fuels and the city, the focus shifts to the Texas Coast as a geopolitical territory of petrochemical production and logistics, describing a unique urban typology. Investigating the relationship between the ground and the object, Typological Adaptations are introduced as a method to climate adaptation of the built environment. Zooming in from the large to the small, the macro to the micro, and the territorial to the architectural scale, this work concludes by claiming that we have already entered a Post-Oil Environment. The challenge remains, however, to find proper ways of adaptation.

18 See Horton, "The Trans-Scalar Challenge of Ecology" describing the relationship between anthropogenic processes and scale.

1.b.
OUTLINE & STRUCTURE

The first chapter focuses on the territorial scale, linking major societal shifts of the 18th and 19th centuries to the origins of the large-scale industrial processes which feed oil and gas consumption. It summarizes these societal shifts from the 'Old Regime of the Three Estates,' to the foundation of a new typology enabling the carbon regime by (de)regulating the evolving resource landscape of the industrial age. Furthermore, this chapter argues that the burning of fossil fuels has become as spatial regime, that (trans)formed the urbanization patterns of a new territory. This work investigates the role of architecture and the city in context of global warming, looking at the geographic centers of major origins and drivers of greenhouse-gas emissions. This approach includes critical reflection on both the challenges that come with petrochemical production but also the benefits this industry brought on a regional or even global scale as an engine for economic growth and prosperity. The first chapter defines Spatial Regimes as *"macro-level processes impacting the natural, cultural, and built environment over time"* and as *"drivers of spatial (trans)formation"* that *"affect the way living organisms utilize and interact within space."* Therefore, the Gulf Coast fulfills two critical components of this work serving as a case-study for both the burning of fossil fuels as a spatial regime and as a particular urban typology shaped by this regime.

The second chapter focuses on the urban scale, utilizing the Texas Coast as a geopolitical territory that enabled a new type of settlement: the *'Coastal Oil City.'* This chapter describes harvesting processes in the coastal resource landscape of Texas in different stages of (re)claiming new territories along the Gulf of Mexico. It provides an overview of the challenges in the coastal danger zone and the opportunities for the cities of resource wonderland. Lastly, this chapter shows a new type of city in the transition period from farmers and cowboys to becoming global oilmen within the Coastal Oil City of Texas. Texas' coastal territories are a prime example of a petrochemical landscape, contributing to and experiencing the impacts of climate change. The timely relevance of the Texas Coast, and particularly fossil fuel production, has increased within the recent process of re-industrialization along the Gulf Coast after the US oil-export embargo was lifted in 2015.[19] Cities and regions along the Texas Coast have been undergoing a petrochemical renaissance as the State of Texas has regained its role as global fossil-fuel-superpower. This work provides a historical outline from the early days of colonization of the United States, railroad expansion, the founding of new cities, and the critical infrastructure needed for the economic operations of Texas' Oil Cities. This analysis shows how the regime of Western capitalism enabled the subdivision of land into private ownership. It links the deregulation of the global market to the subdivision of land and mineral rights, shifting resource-based wealth away from the public domain. The typology of the "Coastal Oil City" in Texas, can be identified by a combination of natural, cultural, and built features, divided into three major components of this urban typology: the (1) Barrier Island, (2) Productive Bay, and (3) Drilling Hinterland. The typological elements of the Coastal Oil City are drivers for spatial development and include the (1) Port, (2) Plant Cluster, (3) Cargo Lines, (4) Consumer Corridor, (5) Suburban Division, (6) Vacation Village, and (7) Beach Strip. Throughout the chapters, the role of each of these elements feeding into the urban processes establishing this typology are explained.

The third chapter focuses on the architectural object scale, addressing climate change as a vertical problem. A historical analysis of 'Typology' in architecture leads to the primary hypothesis of this work, claiming typology as a method for climate adaptation. This chapter gives a general understanding of architectural adaptation, describing the sectional problem constituted by Climate Change. It outlines how designing with types has been and could be a method for typological adaptation of architecture and the city. While the first two chapters serve to outline and identify major challenges forming the described urban typology, the core of this book shows analytical drawings and diagrams, claiming typological adaptation as a key method for architects and urbanists in battling climate change from a design perspective. The etymological origins of the term typology derive from the Greek *'typos'* for *'type'* and the suffix *'ology'* which refers to a *'study of.'* Typology can, therefore, be

19 See GAO, "Crude Oil Markets: Effects of the Repeal of the Crude Oil Export Ban."

summarized as the *'study of types.'*[20] Typology as a method in architecture has been described by influential theorists over the past 150 years, from Jean-Nicolas-Louis Durand, Antoine-Chrysostome Quatremère de Quincy, Aldo Rossi, to Rafael Moneo and others. As described in the chapters later on, Durand captures a crucial concept of type that best describes the goal of this work, stating that types evolve based on shifts in society, or changes in site conditions.[21] In that sense, the societal shifts during the different stages of industrialization, paired with the environmental impacts that alter the conditions of architecture and the city, make a discussion on type relevant as the discipline engages climate change. Defining climate change as a sectional problem, the typological adaptation method proposed in this work suggests 12 types, each establishing a particular object-to-ground relationship. These types are (a) Grounded, (b) Excavated, (c) Underground, (d) Elevated, (e) Raised, (f) Extended, (g) Mobile, (h) Flying, (i) Floating, (j) Submerged, (k) Protected, and (j) Enclosed.

Lastly, this book concludes all chapters by going back to the premise for this work: the claim that we already live in a Post-Oil Environment. The conclusion links the typological approach to adaptation of architecture and the city, describing the current transition-period away from carbon-dependency towards a collective ecological awareness of human-based climate change.[22,23,24]

20 The definition refers to the Cambridge Dictionary, "Typology."

21 Cf. Durand, "Partie Graphique Des Cours d'architecture Faits a l'ecole Royale Polytechnique Depuis Sa Réorganisation; English: Précis of the Lectures on Architecture; with Graphic Portion of the Lectures on Architecture." pp. 48-49

22 See Jenewein, "The Texas Coast as Geopolitical Territory: The Spatial Regime of Burning Fossil Fuels in Coastal Landscapes of Oil."

23 See Jenewein, "The Frequency of (in-)Dependence: A Post-Oil Future in a Post-Pandemic World." p. 119

24 See Jenewein, "Post-Oil Environments."

1.c. RESEARCH QUESTION, HYPOTHESIS & METHODS

This book offers a novel perspective on architecture, framing it as an integral part of the larger urban ecosystem. Emphasizing the interconnectedness between individual architectural objects and the broader context of cities within the global resource landscape highlights the importance of considering environmental factors in architectural design.

A key objective of this book is to delve into how architecture can effectively tackle the challenges brought about by climate change. This work fills a crucial research gap in the field of architecture, particularly in the context of typology. Despite being described as the core of the discipline for centuries, typology has yet to be contextualized within the realm of anthropogenic climate change. Hence, this book bridges this gap, highlighting the potential of typology as a transscalar approach to climate adaptation across scales. It approaches this question through a transscalar lens, examining the vertical relationship between architectural elements and the ground across various scales, from the territorial to the urban to the architectural. Furthermore, this work primarily focuses on the vertical relationship between architecture and the ground to reduce the complexity and scope, linking the discourse on resource extraction, carbon emissions, and sea-level rise into one formal problem that architecture needs to adapt to.

This book employs a comprehensive range of research methods to explore its subject matter. These include literature review, geospatial mapping, drawing, diagramming, and visualization. By utilizing these diverse methods, the book aims to untangle the complex relationships between context and form, with the ultimate goal of informing and inspiring architectural responses that foster climate adaptation and sustainability within the built environment.

PROBLEM

PROBLEM

The burning of fossil fuels has evolved into a spatial regime, generating urban typologies that are on the forefront of contributing to and experiencing the impacts of climate change. Over decades, cities within these oil environments flourished but now struggle to adapt as the architecture of the city sits on increasingly unstable grounds.

QUESTION

QUESTION

How can architecture develop a disciplinary response to climate change, addressing the vertical relationship between the natural and the built, the ground and the object, the landscape and the city?

HYPOTHESIS

HYPOTHESIS

Living in a Post-Oil Environment, Typological Adaptation can be utilized as a climate adaptation method for architecture and the city.

METHODS

METHODS

Structured as a transscalar investigation focusing on the vertical relationship between the architectural object and the ground, this work zooms from the territorial across the urban to the architectural scale and utilizes literature review, geospatial mapping, drawing, diagramming, and data visualizing as major methods.

02

Spatial Regimes

(trans)Forming
Urbanization Patterns

02

Territorial Scale

SPATIAL REGIMES

(trans)Forming
Urbanization Patterns

Spatial Regimes are macro-level processes impacting the natural, cultural, and built environment over time. They are drivers of spatial (trans)formation and affect the way living organisms utilize and interact within space. The term »regimes« originates from Latin "regimen" meaning "rule" and has been appropriated to describe space-defining rules or parameters and their physical implications on space in this work. The origin of these manifestations can either be natural or anthropogenic. As the burning of fossil fuels is a macro-level process impacting the natural, cultural, and built environment over time, this work hypothesizes that the burning of fossil fuels has evolved into a spatial regime. In these times of changing weather patterns, shifting edges of land and water, and dematerializing facets of everyday life, it is crucial to understand the origins and drivers of transformation. This chapter provides an overview on how changes in land ownership, paired with technological progress and new modes of transportation, transformed urbanization patterns becoming both a cause and driver of climate change.

The early years of the 2020s have highlighted opportunities, challenges, and especially the limits of a globalized world. In the accelerating process of humans interfering with nature, the climate crisis met a health crisis spread by the global logistics network. As the Coronavirus traveled onboard crude carriers, cruise ships, passenger and cargo planes, trains, cars, and bicycles alike, the interconnectedness between public health and the way humans move and interact within and across the built environment became visible.

In their 2020 Report on Climate Change, the United Nations link the COVID-19 Pandemic to the climate crisis.[1]

> *"COVID-19 and climate change are interconnected: as natural habitats shrink, in part owing to climate change, humans and animals come in contact more frequently, giving viruses, parasites and bacteria more opportunities to jump from one species to another and spread. The crises are also similar: both are global in nature, and both require emergency responses and adjustments to medium- and long-term planning. Neither crisis knows borders, and both impact everyone. Both crises affect the most vulnerable people the most. And the remedy to both crises requires not only science-based approaches, but also international cooperation and responsible behaviour at all levels of society."*
>
> *- UNITED NATIONS REPORT ON CLIMATE CHANGE, 2020*

Describing the similarities between climate change and COVID-19 leads to the question of what type of crises humankind is facing here. In an attempt to understand climate change and COVID-19 as different models of the same type of crisis, shared characteristics need to be identified. Following the Unit-

1 Cf. UNFCC, United Nations Climate Change, Annual Report 2020. p. 11-14

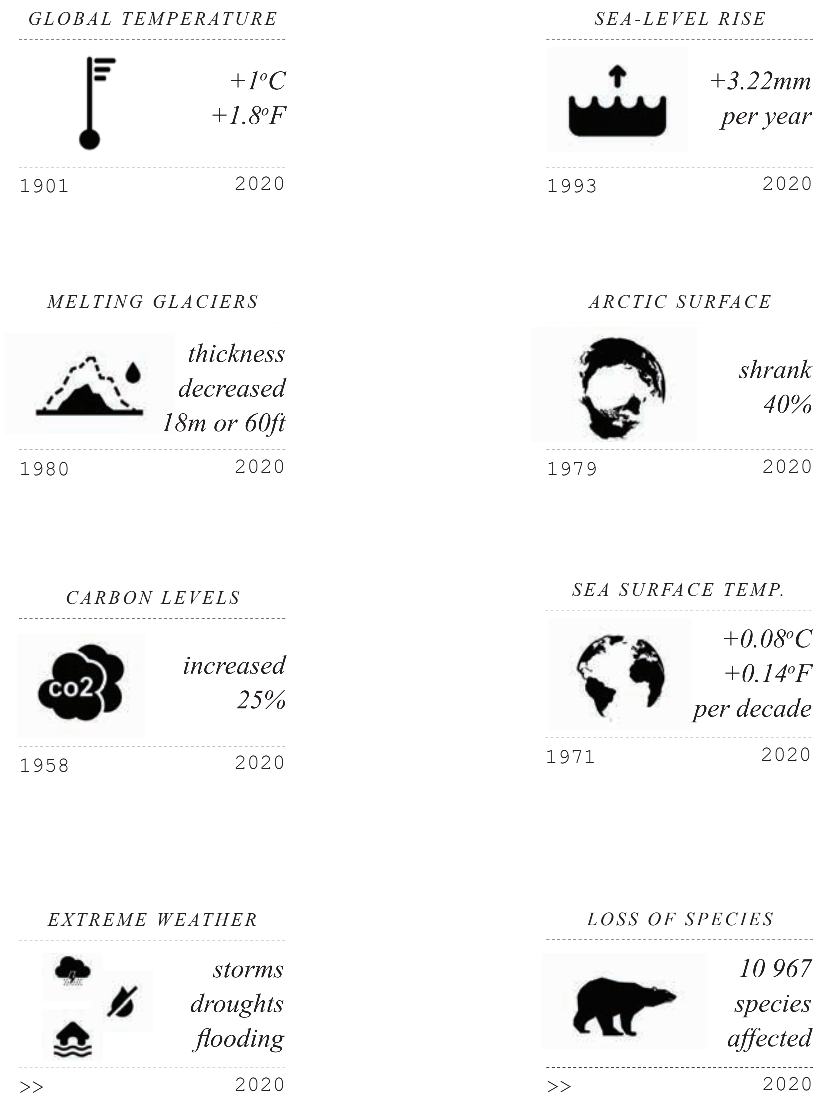


Figure 5. Several significant climate change indicators highlight the impact of global warming on the ecosystem. Global temperature, sea-level rise, melting glaciers, shrinking arctic surfaces, increased carbon levels, sea-surface temperatures, extreme weather patterns, and loss of species are some of these indicators. (Data extracted from NOAA, "Climate Change Impacts.")

ed Nations' outline, these characteristics can be summarized describing a (1) spatial correlation, being global crises, (2) time correlation, being mid to long-term crises, (3) political correlation, ignoring borders, (4) social correlation, affecting everyone, (5) (in)justice correlation, impacting vulnerable groups the most, an (6) urgency correlation, requiring immediate responses, (7) collaborative correlation, asking for multidisciplinary public-private partnerships to act, and a (8) behavioral correlation, requiring individual responsibility. In contrast, climate change and COVID-19 also share fundamental differences, especially in terms of how visible the respective impacts are to the public. While infection rates, hospitalizations, and death cases due to COVID-19 have been increasing and decreasing relatively fast, climate change impacts are often delayed for decades and may not immediately be Seen in response to specific causes. Besides, understanding what types of crisis climate change or COVID-19 are, the most important question is how to solve it. And to find solutions for any type of crises, it is crucial to understand its origins to distinguish causes from symptoms.[2]

Deforestation, agriculture, food production, and fossil fuels contribute unprecedented amounts of carbon dioxide, methane, nitrous oxide, and chlorofluorocarbon-12 into the air.[3] The trapped hydrocarbons in the atmosphere block infrared radiation from leaving the atmosphere, leading to a rise in global temperature. The rise in temperature forces ice to melt and sea levels to rise. The melting of glaciers during warm periods fills rivers and dams with more water.[4] Changing weather patterns can bring extended periods of drought or rain. These climate change impacts all lead ultimately to various types of flooding. While rising seas threaten coastal areas to flood, inland areas may flood due to river flooding. In addition, more extreme rainfalls might impose additional stress on the urban infrastructure as an enormous amount of rain during peak events may overload stormwater systems and exceed the natural drainage capacity.[5]

2 Ibid.

3 Cf. EIA, "Energy and the Environment Explained: Where Greenhouse Gases Come From."

4 Cf. NOAA, "Climate Change: Atmospheric Carbon Dioxide."

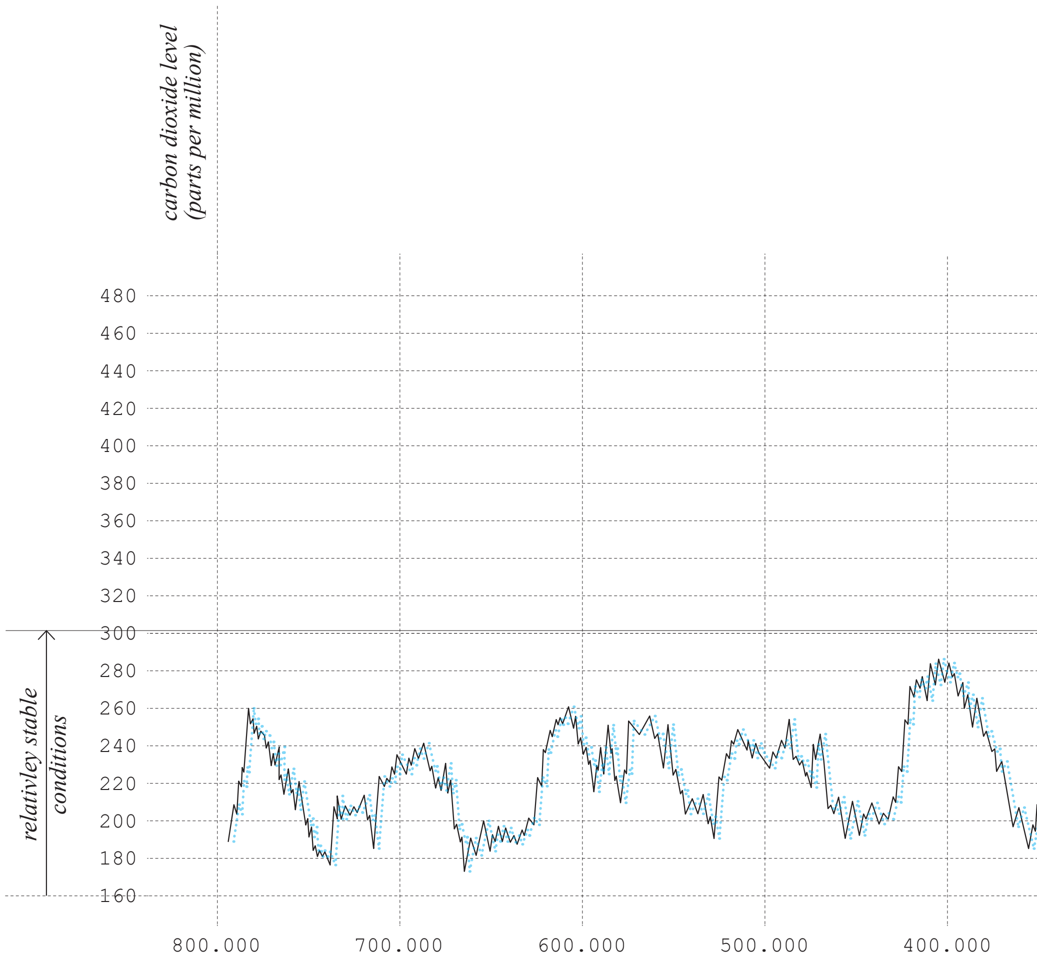
5 Cf. Joyce et al., "Climate Change Impacts in the United States Forests."

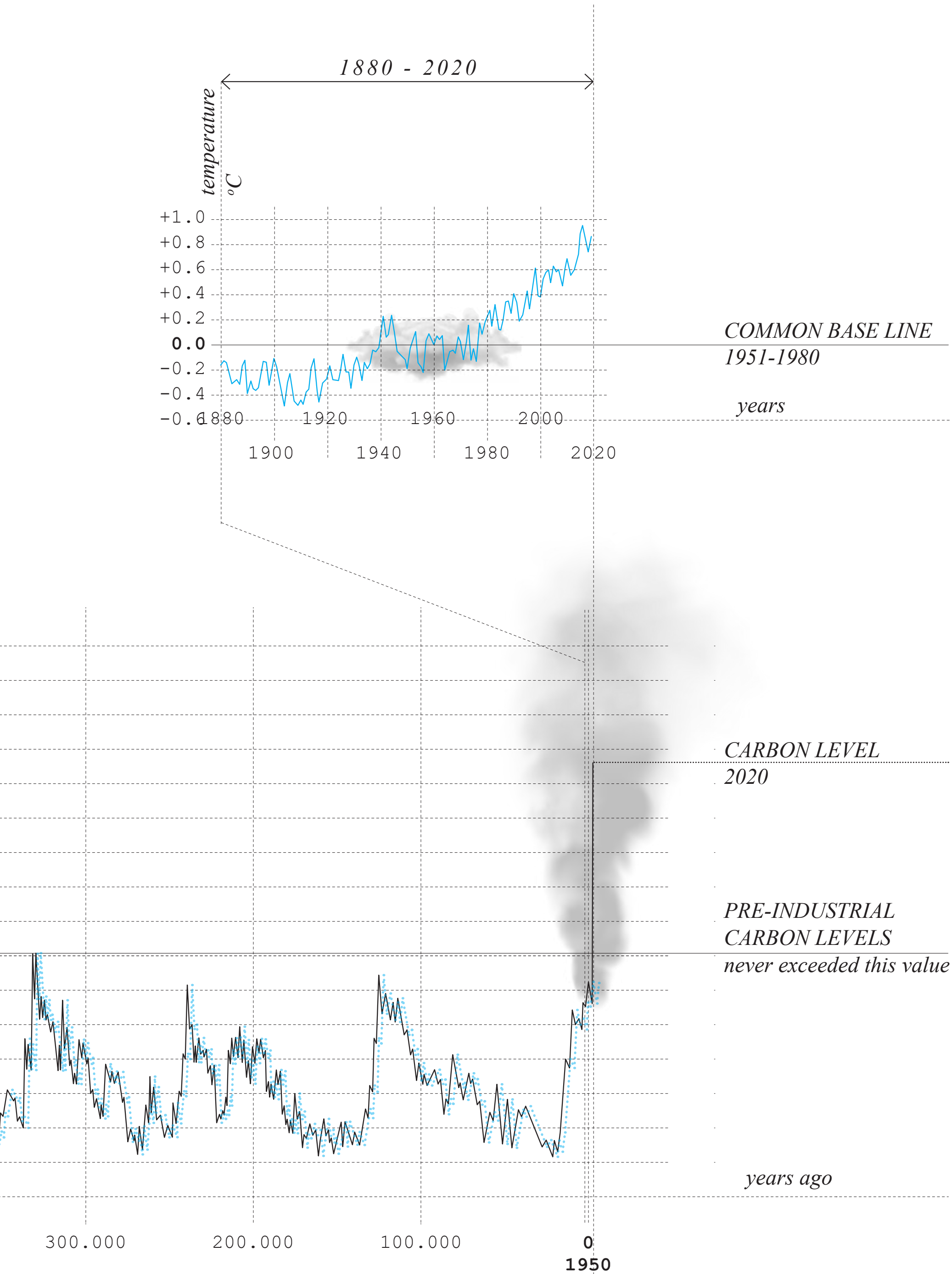
In the emerging 21st century, climate change symptoms have become a lot more visible. Research findings of the National Oceanic Atmospheric Administration (NOAA) confirm a +1°C (+1.8°F) rise in global temperature since 1901. Simultaneously, the global carbon level in the atmosphere increased 40 percent since the beginning of the Industrial Revolution and about 25 percent since 1958. In response, sea-levels have started to rise about 3.2 millimeters per year, or 21-24 centimeters (8-9 inches) in total since 1880. Climate change impacts within and around water generally represent a major type of environmental repercussions. While the surface of the Arctic ice layer has decreased 40 percent since 1979, major glaciers have lost 18 meters (60 feet) of thickness over the same time-period.[6] This process is related to the increasing temperature of the world's oceans. Both the surface temperature and the heat stored in the oceans are generally rising, yet with regional differences. Some areas are heating up faster than others, some are cooling down.[7] Furthermore, extreme weather conditions have significantly increased over the 20th century. While unusually intense rainfalls and precipitation events increase the risk of flooding, extended dry periods have also become more frequent.[8] The risks associated with climate change also heavily impact human health. Despite technological advancements, agricultural processes can be impacted by extreme weather events like droughts and heavy rainfalls. Temporary or long-term changes in regional weather patterns disrupt food or water supply.[9] Simultaneously, shifting weather patterns also bring new species and disease-carrying vermin like insects or small animals. Such vermin could harm crops, live-stock or spread contagious diseases.[10]

These changes in environmental conditions, from ocean heat to atmospheric carbon levels and from more frequent storm events to rising temperatures and sea levels, strongly impact the global ecosystem. Thousands of species are affected by these changes as habitat disruptions could substantially

6 See NOAA, "Climate Change Impacts."
7 See EPA, "Climate Change Indicators: Oceans."
8 See EPA, "Climate Change Indicators: Heavy Precipitation."
9 Cf. CDC, "Climate Change Increases in the Number and Geographic Range of Disease-Carrying Sects and Ticks."
10 Ibid.

Figure 6. The analysis of historical data shows a correlation between rising carbon levels in the atmosphere and rising temperatures. Since the beginning of the Industrial Revolution, increasing levels of carbon dioxide have been released into the air, leading to global warming. (Data source: NOAA, “Climate Change: Atmospheric Carbon Dioxide.”)




1880 - 2020
temperature
°C
+1.0
+0.8
+0.6
+0.4
+0.2
0.0
-0.2
-0.4
-0.6
1880
1920
1960
2000
1900
1940
1980
2020
COMMON BASE LINE
1951-1980
years
CARBON LEVEL
2020
PRE-INDUSTRIAL
CARBON LEVELS
never exceeded this value
years ago
300.000
200.000
100.000
0
1950

harm their health or even their existence. In addition, an increasing amount of wildfires, changes in stream-flows and temperatures, water temperatures, bloom cycles, and other factors play a crucial role in the natural habitats on land, in water, and in air.[11]

As the causes, drivers, and impacts of climate change are reshaping the formation of the natural, cultural, and built landscape, it is crucial to understand how these conditions now demand a new type of architecture in the city.

2.a.
ABOLISHING THE OLD REGIME: THE FOUNDATION OF A NEW TYPOLOGY

Towards the end of the 18th century, the world was occupied by just over 800 million people.[12] Over the one thousand years prior to that, the world's population had roughly tripled. Over the following 200 years, the population has increased nine times, climbing to almost 8 billion people in the 2020s.[13] At the dawn of the Industrial Revolution, the world entered the age of rapid growth, harvesting, producing, burning, and wasting nature's resources at an unprecedented pace and scale.

The increasing unrest in the colonies and the collective desire for freedom and equality unleashed the synergies of the Enlightenment Era, enabling more people to read and write than ever before. With a growing percentage of the population being able to distribute knowledge across kingdoms, regions, and continents, groundbreaking ideas and even more spectacular inventions traveled over the seven seas. Some of these inventions should drastically change

11 Cf. USGCRP, "USGCRP Indicator Platform."
12 These world population estimates are based on Census Bureau, "Historical Estimates of World Population."
13 Ibid.

the way we harvest crops, raise cattle, move from place to place, produce goods, and communicate with each other. In addition, new ideas started to radically reorganize the political landscape and change socio-economic patterns that had been formed over centuries. With the demand of "*Liberté! Egalité! Fraternité!*" (Liberty, Equality, Fraternity) in 1789, the French Revolution set a chain of events in motion that would ultimately restructure wealth.[14] The days of monarchies as political and societal regimes were counted, as the emerging idea of a republic gained more traction. Aiming to end the era of imperial policies, the 13 American Colonies gained independence from Great Britain in 1776, just a few years prior to the Revolution in allied France.[15] The French Revolution as a movement of political and social reform overthrowing the class-system of 18th century enabled a variety of fundamental changes in policy and law. At the dawn of the revolution, a cadastral survey of the distribution of land formed the basis for the taxation of land.[16] In an attempt to solve the monarchy's financial crisis, a redistribution of church property, covering approximately 6.5 percent of territory, reshaped the power landscape of France.[17] With this reallocation of property sold in auctions, noble privileges and feudal institutions started to dismantle the *Old Regime of the Three Estates*: the clergy, nobles, and commoners (peasants and bourgeoisie). Alongside the abolishment of the Feudal System, the distribution of large estates and the associated policy changes, the process of privatizing land had begun.[18]

> *"When in 1789 land became free, the large estates of the aristocracy and the clergy were sold to the middle class and to farmers. But just as all of the landed rights of the nobility were largely dissolved, so also were those of the*

14 Cf. The National Archives, "The French Revolution How Did the British React to July 1789?"
15 Cf. Office of the Historian, "The Declaration of Independence."
16 Cf. De Tocqueville, The Old Regime and the French Revolution. pp. 2-24
17 Cf. Finley, Franck, and Johnson, "The Effects of Land Redistribution: Evidence from the French Revolution." pp. 233-244.
18 Ibid. pp. 245-267.

communes, and thus the great state-owned areas were broken up. The monopoly on land was transformed into private ownership; land became a marketable entity like anything else."[19]

> ALDO ROSSI: THE ARCHITECTURE OF THE CITY, 1982

Both Bernoulli[20] and Rossi[21] describe this process of subdividing land in their works as changes of land ownership and the redrawing of communal lands into smaller plots significantly impacted the development of cities. On the pathway to modern capitalism, land became a private good of speculation.

"The land casually slipped away from the community and fell into hands of prudent farmers and shrewd citizens, where it quickly became an object of true and real speculation. [...] The city found itself once again at that turn in the road where the right of private ownership of land was manifested in full in new building establishments. The new times, unexpectedly awakening to another industrial activity, gave proprietors an almost unbounded possibility to increase the value of their own lands."[22]

> HANS BERNOULLI: DIE STADT UND IHR BODEN, 1946

Across the Atlantic, cities in the independent United States continued to grow. In addition, numerous cities were founded throughout America's frontier, the

19 Rossi, The Architecture of the City. p. 152
20 Cf. Brenoulli describes the process of land subdivision associated with societal changes in Bernoulli and Novy, Die Stadt Und Ihr Boden. pp. 70-72
21 Cf. Rossi refers to Bernoulli's writings as he describes the subdivision of land into private ownership in Rossi, The Architecture of the City. p. 152
22 Rossi, The Architecture of the City. p. 153

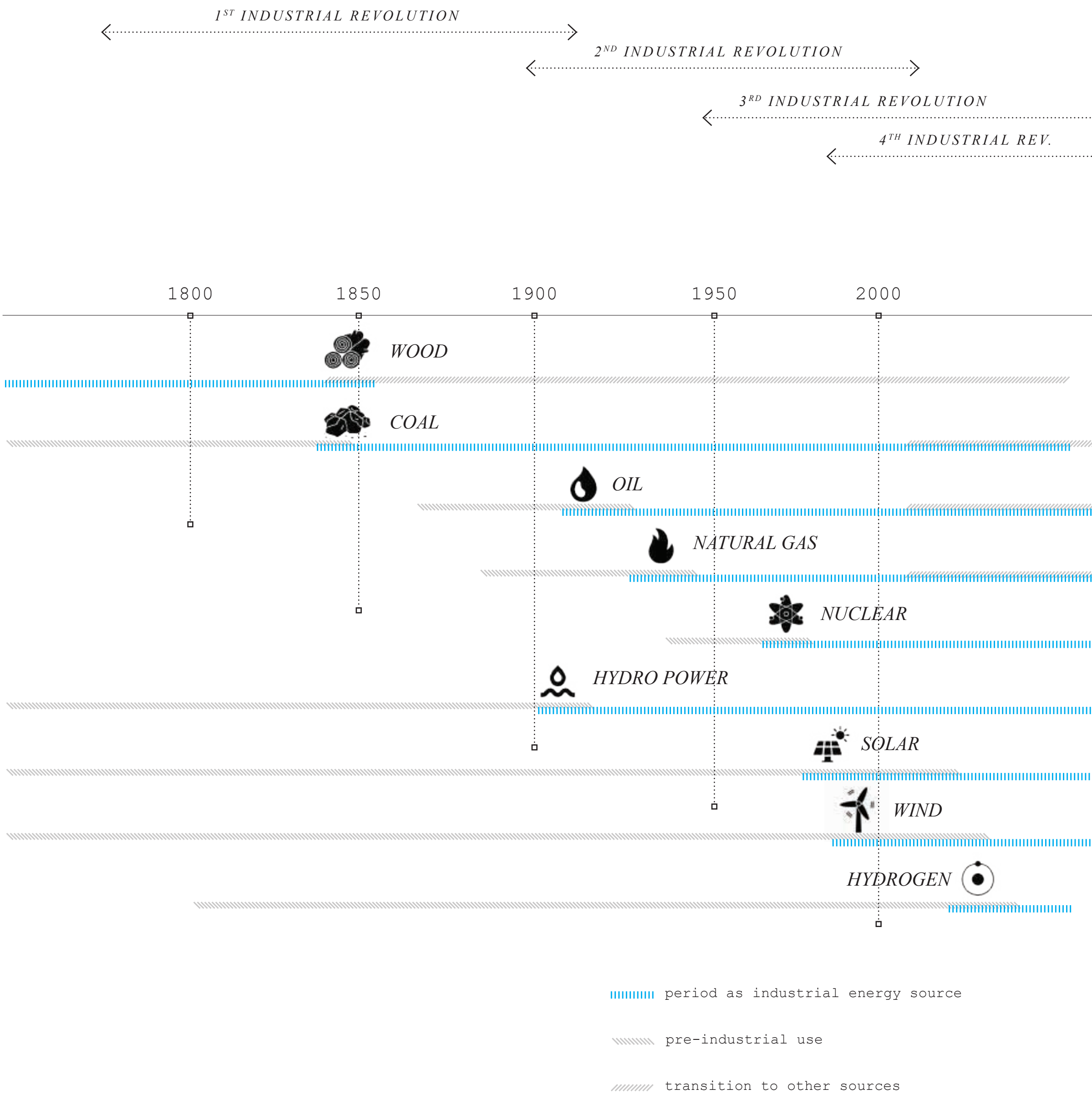


Figure 7. This timeline of major energy sources in different stages of the Industrial Revolution shows the dependency of fossil-fuel based energy sources like coal, oil, and natural gas.

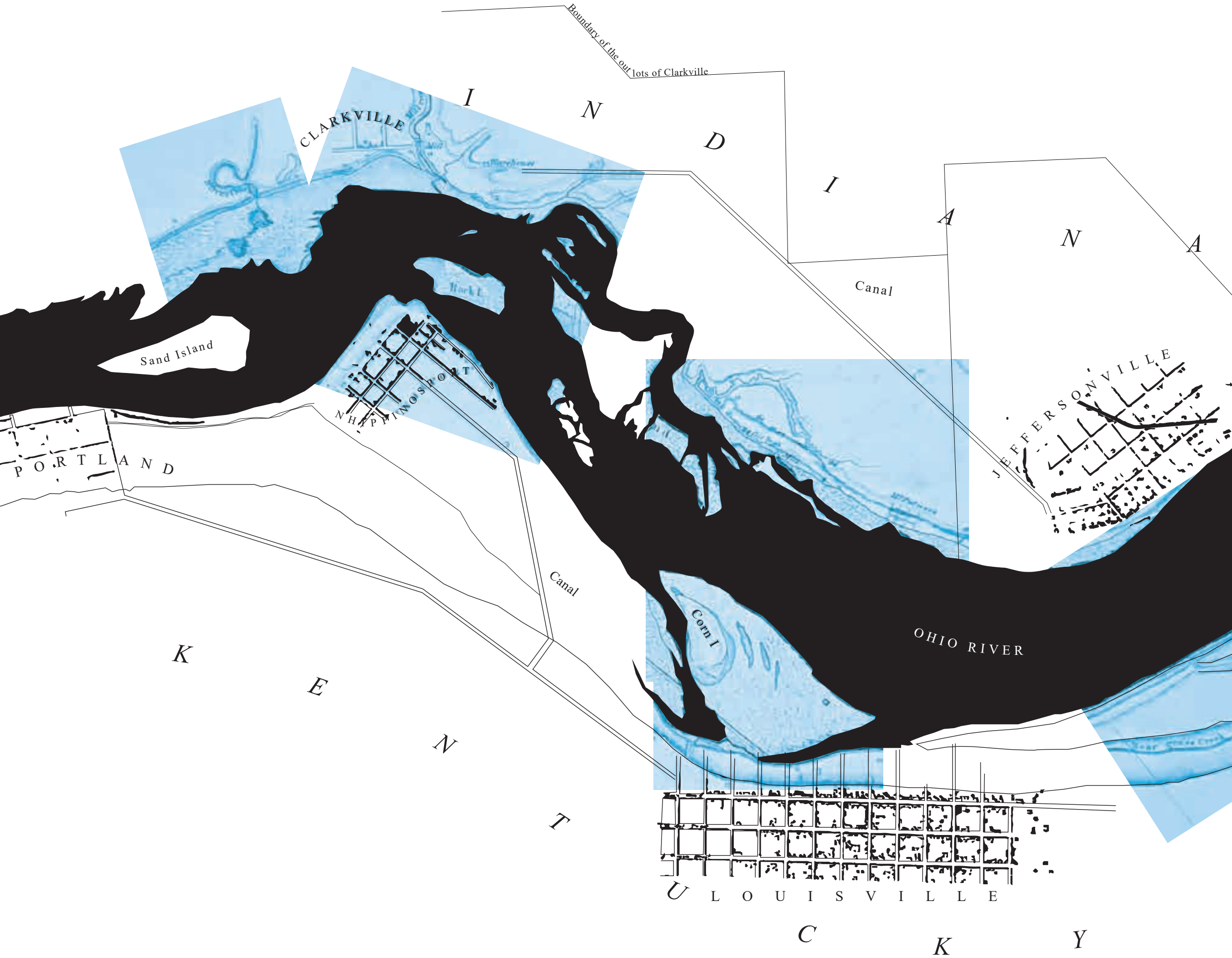


Figure 8. Map of towns founded along the Ohio River of 1824. (Image appropriated from Reps, "The Making of Urban America: A History of City Planning in the United States." p. 362)

expansion of territories towards the west coast. The concept of land as a marketable good shaped the process of urbanization well before the French Revolution reorganized property-based wealth in continental Europe. John W. Reps authored a significant book about the history of cities in the United States titled *"The Making of Urban America."* Reps outlines how land speculation has quickly become a part of American cities as a major motive in town planning soon after colonial settlers had set foot on the new continent.[23]

23 Reps, "The Making of Urban America: A History of City Planning in the United States." p. 349

"Gain! Gain! Gain! is the beginning, the middle and the end, the alpha and omega of the founders of American towns ..."[24]

> *MORRIS BIRKBECK, NOTES ON A JOURNEY IN AMERICA FROM THE COAST OF VIRGINIA TO THE TERRITORY OF ILLINOIS, 1818*

While the early settlements of the East Coast, the New England settlements of Virginia, primarily served as an agricultural settlement and gateway to the hinterland, land speculation became a more common practice as the years passed. It was not until mid-century, around 1750, when several land companies had formed in an attempt to acquire land-grants from the British Crown to develop towns. Subdividing land into town-lots, out-lots, and garden- or farm-lots became the prevalent model of establishing towns by land companies in the late 18th century. Though the settlement process was interrupted by the Revolutionary War that transformed former British America into the independent United States of America, the formation of new towns heading west continued soon after.[25]

Investigating the territorial scale with a focus on where towns were founded shows that locations along principle rivers connecting inland regions to the coast were the prime sites of speculative interest. For example, the Ohio River served as a breeding ground feeding numerous new towns along its river beds by enabling river-bound transportation and trade. As steamboats started to utilize rivers, riverfront locations seemed to be a great investment. The dredging of canals started to become a feasible concept to connect towns that initially did not have river access. The land developers at the time did not know that the arrival of the railroad a few years later would reduce the competitiveness of river and canal-front cities.[26]

In the emerging 19th century, railroads started to stimulate growth of the existing towns of the East Coast and enabled hundreds of new cities in Amer-

24 Birkbeck, Notes on a Journey in America, from the Coast of Virginia to the Territory of Illinois. p. 69
25 Ibid. pp. 350-351
26 Ibid. p. 361

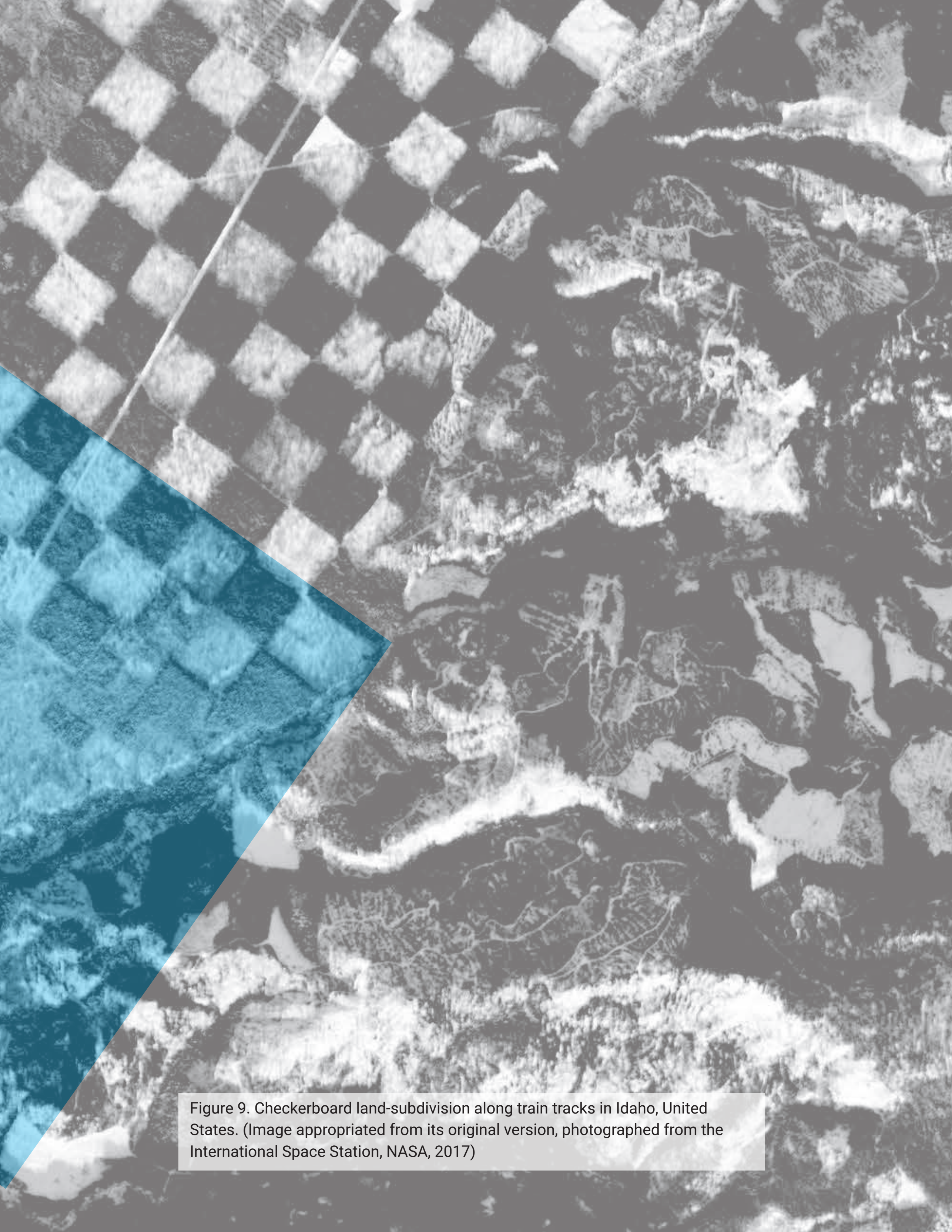


Figure 9. Checkerboard land-subdivision along train tracks in Idaho, United States. (Image appropriated from its original version, photographed from the International Space Station, NASA, 2017)

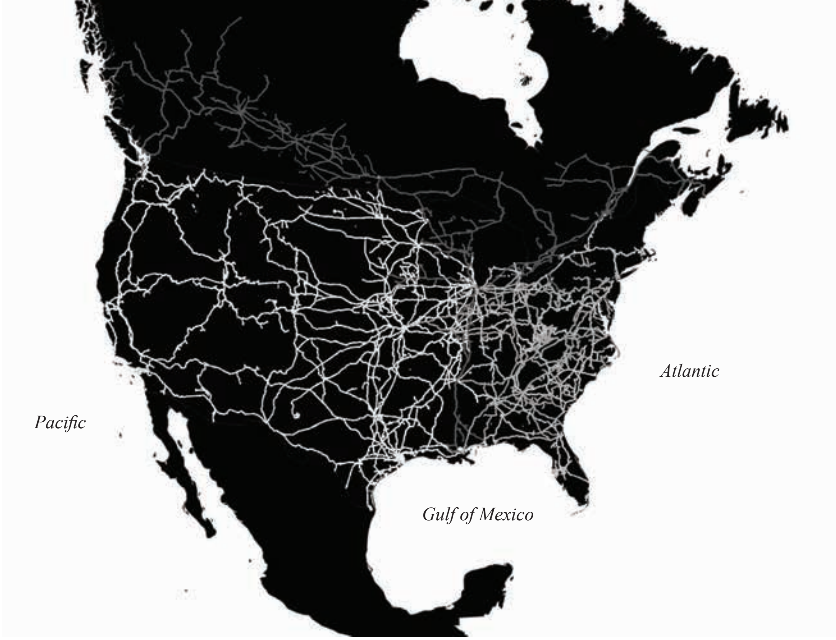


Figure 10. The North American Railroad Networks in 2018 show that the track density decreases from east to west. (content appropriated from Soundingmaps)

ica's frontier. The emergence of rail lines introduced new typologies of urban infrastructure necessary for railroad operation into towns. Besides the stations and shipping yards themselves, railroads quickly evolved into a transportation network serving as a new premise for settlement as the immediate proximity to a river or canal for transportation purposes was no longer essential.[27] In the process of constructing a transcontinental railroad network spanning from coast to coast, "*Railway Towns,*" also called "*Hell on Wheels,*"[28] emerged as an urban typology along the tracks. Their primary function was to serve as a home base for construction workers and depot for the materials needed to construct the transcontinental line. Railway Towns were often abandoned quickly after the construction workforce moved ahead following the rail lines.[29]

By mid-century, European colonial influence decreased drastically. With the Louisiana Purchase, the annexation of Texas, and the Mexican Cession, the young United States stretched from coast-to-coast, from Virginia to Califor-

27 Ibid. p. 382
28 See Klein, Union Pacific: 1862-1893. pp. 100–101
29 Cf. Reps, "The Making of Urban America: A History of City Planning in the United States." p. 400

nia, and from Illinois to Texas. As the transcontinental railway construction continued, the first coast to coast rail connection was completed in 1869.[30] Railways became even bigger catalysts for development, enabling breeding grounds for one town after the other. Land companies, builders, planners, and promoters promised a wonderland of rapidly growing cities, wealth, and prosperity built on the speculative lands aside the rails.

The Old Regime of ownership came to an end at a time of fundamental change. This transition period to a new political and social order in Europe, across the colonies, and the newly formed independent countries of the Americas, now enabling ordinary citizens to own land, made land speculation a fundamental pillar for town-planning across the continental United States. Driven by a hunger for profit, land developers promised growth that in many cases never arrived. Simultaneously, the rise of steam-powered inventions and technological progress brought new means of transportation with a significant spatial impact, as the formation of cities would no longer be tied to a coast, river, or canal. The way products used to be manufactured across continental Europe, Great Britain, and the United States were about to drastically change too. These changes of the First Industrial Revolution in the late 18th and early 19th century paved the way for a new regime. A regime that enabled growth at an unprecedented scale. A regime fueled by crude oil and natural gas.

30 Cf. Library of Congress, “The Transcontinental Railroad.”

2.b.
ENABLING THE CARBON REGIME: (de)REGULATING THE RESOURCE LANDSCAPE

While the 18th and 19th century revolutions brought long-lasting changes to the socio-political landscape, paving the way for the upcoming democracies of the Western World, new energy sources were needed to fuel this time of growth. Even though coal had been used as an energy source for centuries, wood was the prevailing material up until the Middle Ages. In England and Wales, the share of coal as energy source rose from only 10 percent in 1560, and then doubled from 35 percent in 1660 to 64 percent in 1760. By 1860, coal had increased its role as a crucial commodity, fueling 93 percent of England's energy demand.[31] Similarly, wood remained a significant energy source in the United States until the transition to coal as a more efficient material had outperformed wood by the mid-19th century.

With the changing energy landscape, rivers and human-made waterways were no longer needed as strategic transportation routes enabling wood or coal supply. With the rise of steam engines, human- and animal-powered processes could suddenly be replaced by machines. Unlike wood, coal is a non-renewable resource. While forests regenerate wood-supply cyclically, entering the age of coal mining meant utilizing finite resources to fulfill energy demand.

> *"Until 200 years ago, the energy needed to sustain human existence came almost entirely from renewable sources."*[32]
>
> *> TIMOTHY MITCHELL: CARBON DEMOCRACY, 2011*

31 See Allen, "Energy Transitions in History: The Shift to Coal." pp. 11–15.
32 Mitchell, Carbon Democracy: Political Power in the Age of Oil. p. 12

The question of energy source and demand also had a spatial correlation to it. When wood was no longer needed to cook, heat, or for various industrial processes, the dependence of cities on forests located in proximity disappeared.[33]

In his book "*The Coal Question*" from 1865, William Stanley Jevons addresses the growing energy demand in England, highlighting how the increased efficiency in coal processing led to increased energy demand. This phenomenon is also known as the "*Rebound Effect*" or "*Jevons' Paradox*," summarizing how technological progress makes materials like coal or iron more efficient to use.[34] On the one hand, increased efficiency drops prices as production becomes faster and cheaper. On the other hand, the more energy becomes available at a lower price, the more energy is consumed. Thus, instead of utilizing the efficiency gains to conserve raw materials, consumption rises, and even more energy is needed.[35]

> *"Gains in efficiency, result in increased consumption."*[36]
>
> *> WILLIAM STANLEY JEVONS: JEVONS' PARADOX, 1865*

While the successful exploration of coal and iron ore powered the early stages of industrialization throughout Europe, solar-based production of cotton or sugar conquered the colonies from Asia to the New World. Though Europe had increased its industrial coal operations, the solar-powered cultivation of crops in the colonies was a large-scale agricultural undertaking built on the backs of imported slaves.[37] It would not take long, however, until coal production picked up in the young United States as well. The increased demand for both industrial and agricultural production shaped the landscapes of the 19th century in Europe and America alike.

33 Cf. Mitchell, Carbon Democracy: Political Power in the Age of Oil. pp. 12-15

34 See Jenewein, "The Frequency of (in-)Dependence: A Post-Oil Future in a Post-Pandemic World. Case-Study Texas Coast in the Time of COVID-19." pp. 112-119

35 Cf. Alcott, "Jevons' Paradox." pp.9-21.

36 Ibid.

37 Cf. Mitchell, Carbon Democracy: Political Power in the Age of Oil. pp. 15-18

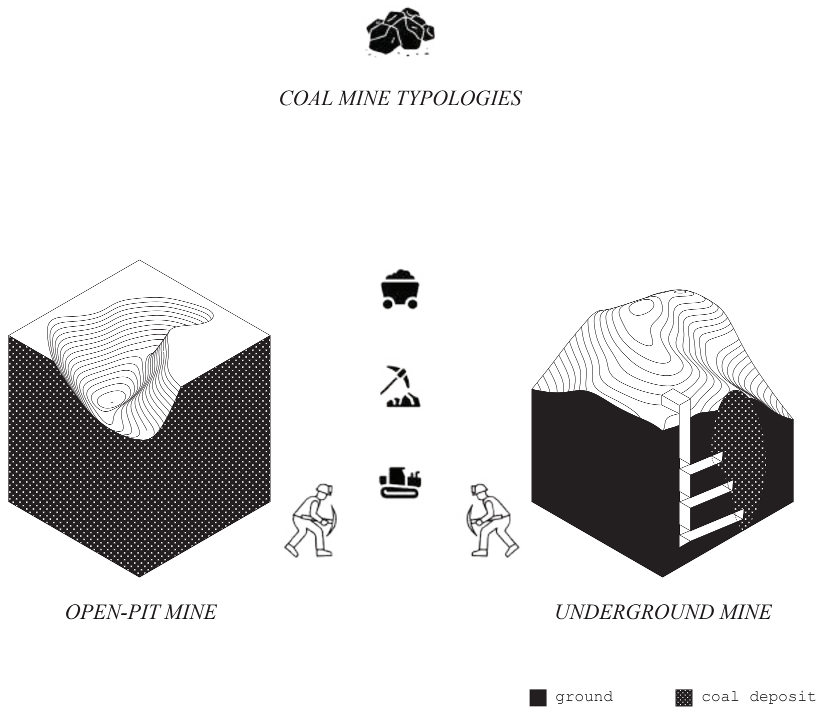


Figure 11. The two major types of coal mining, open-pit and underground mining, alter the earth's surface to extract resources.

While the origins of commercial coal mining in the US go back to the early 18th century in Richmond, Virginia, large-scale industrial mining began around 1775 in Pennsylvania.[38] The Appalachian mountains have then developed into a major coal region with active mines operating until today. The exploration of coal continued with the westward expansion of US territory. As of 2020, Wyoming, North Dakota, Illinois, West Virginia, and Pennsylvania rank among the top five coal-producing states, providing 71 percent of the nation's coal.[39]

38 See NCBI, "Coal Mining in the United States."
39 See EIA, "Where the United States Gets Its Coal."

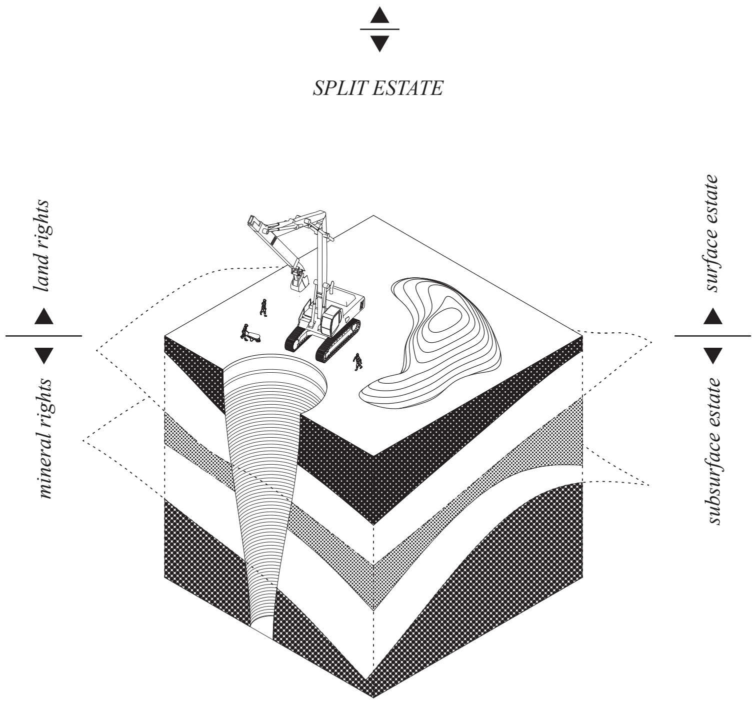


Figure 12. A Split Estate descries land ownership rights which separate surface and sub-surface rights.

Throughout the history of industrial coal mining, health and safety improvements for mine workers were hard fought. The catastrophic work conditions and low wages led to the formation of a series of labor unions towards the end of the 19th century in the United States when the *Knights of Labor* and the *Progressive Union of Miners and Mine Laborers* joined forces merging into the *United Mine Workers of America*.[40] With the formation of new territories, republics, and alliances at the time of rapid industrial progress and hence

40 See UMWA, "United Mine Workers of America History."

surface estate

subsurface estate

PUBLIC LANDS

public / *public*	*public* / *private*	*private* / *public*
federal surface / *federal leased minerals*	*federal surface* / *non-federal minerals*	*non-federal surface* / *federal leased minerals*

Figure 13. A Split Estate, separating surface and subsurface rights, can also divide public and private ownership. The subsurface minerals could be sold or leased to public or private entities as well (appropriated from Grosman, "Of Two Minds: Excavating the Split Estate."). In

economic and population growth, social tensions started to become increasingly visible. Developing adequate conditions for living and working became a goal in urban planning as labor unions started to unite and demand change.

The premise for coal mining is the actual mining site itself. There are two major types of coal mining processes depending on the respective geological formation of the coal deposit: open-pit or surface mines, and underground mines. For open-pit mines, large areas of land are excavated leaving a signif-

the United States, 39.1% of lands are publicly owned, while in Texas, for instance, only 4.2% of lands are publicly owned (data extracted from BLM, "Public Land Statistics 2020.").

icant footprint on the surface. Underground mines, on the other hand, leave a very small footprint on the surface while extracting a significant volume from beneath the surface. Despite the reduced footprint of underground mining on the landscape, the impact on workers' health is a major concern.[41] With increasing industrialization and the rapid westward expansion of the continental United States, land quickly became a desired good. Besides the

41 Cf. BLM, "Mining and Minerals."

actual value of the land as a surface to erect towns, tracks, or factories, plenty of resources could be harvested from it or underneath it. The exploration of natural resources hidden underneath the earth's face formed the premise for settlement in many places. From gold, silver, and other metals to wood, coal, and water, colonial settlers were on a quest to discover the hidden gems of the new continent. The towns along the tracks enabled economic growth as resources could be transported and traded quickly. However, such boomtowns often rose as fast as they disappeared. With the Pacific Railway Act of 1862, the US government granted lands left and right of the train tracks to railroad companies as an incentive for development. With this legislative strategy, *"men of talent, men of character, men who are willing to invest"* should be supported in their efforts of constructing the transcontinental railway.[42] The railway construction became a gigantic privately owned yet publicly subsidized project. The federal government granted the land to private companies, yet kept, in most cases, the mineral rights. While the 200-foot-corridor on both sides of the tracks granted the railroad companies the right of way, it also transferred property rights to the private sector. Minerals should remain to be state-owned assets.

The division of surface and sub-surface, or land and mineral rights, demonstrates how the young democracy of the United States carried over some and abolished other rules and norms from the colonial motherlands. A legal clause known as "*split estate*" allowed surface and subsurface property rights to be owned by two different entities.[43] Land rights could be federally owned while mineral rights were private property or vice versa.[44] As the development of the railroad network occurred at the same time as the discovery of North America's first gigantic oil reserves, mineral exploration, land development, and railroad construction became intertwined endeavors.[45]

42 See United States Senate, "Landmark Legislation: The Pacific Railway Act of 1862."
43 Cf. Grosman, "Of Two Minds: Excavating the Split Estate."
44 Cf. BLM, "Public Land Statistics 2020."
45 Cf. DOI, "Ownership."

> *"The Land Ordinance Act of 1785, the establishment of the Public Land Survey System, and the Northwest Ordinance Act of 1789 set the stage for the trek across the continent. During westward expansion, settled lands were incentivized in large part through the promise of private property ownership. This was done at the expense of Native Americans who were repeatedly and systematically dispossessed of their land by U.S. land use policies, and continues through present-day land-use management practices enacted by the federal government on Tribal lands today. Through this colonialist effort, the uneven geographic distribution of arable soil, water, and minerals translated into unequal development and land ownership as the presence of natural resources stimulated population growth and the Industrial Revolution."*[46]
>
> *> STACIA S. RYDER, PETER M. HALL: THIS LAND IS YOUR LAND, MAYBE, 2017*

Soon after the exploration of oil on land, coastal waters and the related seabeds developed into promising access points for additional carbon reservoirs. Coastal waters had been controlled by the respective states until 1937, when the federal government started to purchase offshore lands from the states. With this change in dominion, the submerged lands along the seabed fell under federal control for a zone of three sea miles.[47] After a series of lawsuits, the Submerged Lands Act of 1953 granted states the ownership rights of the seabed and resources within three sea miles from their coast.[48]

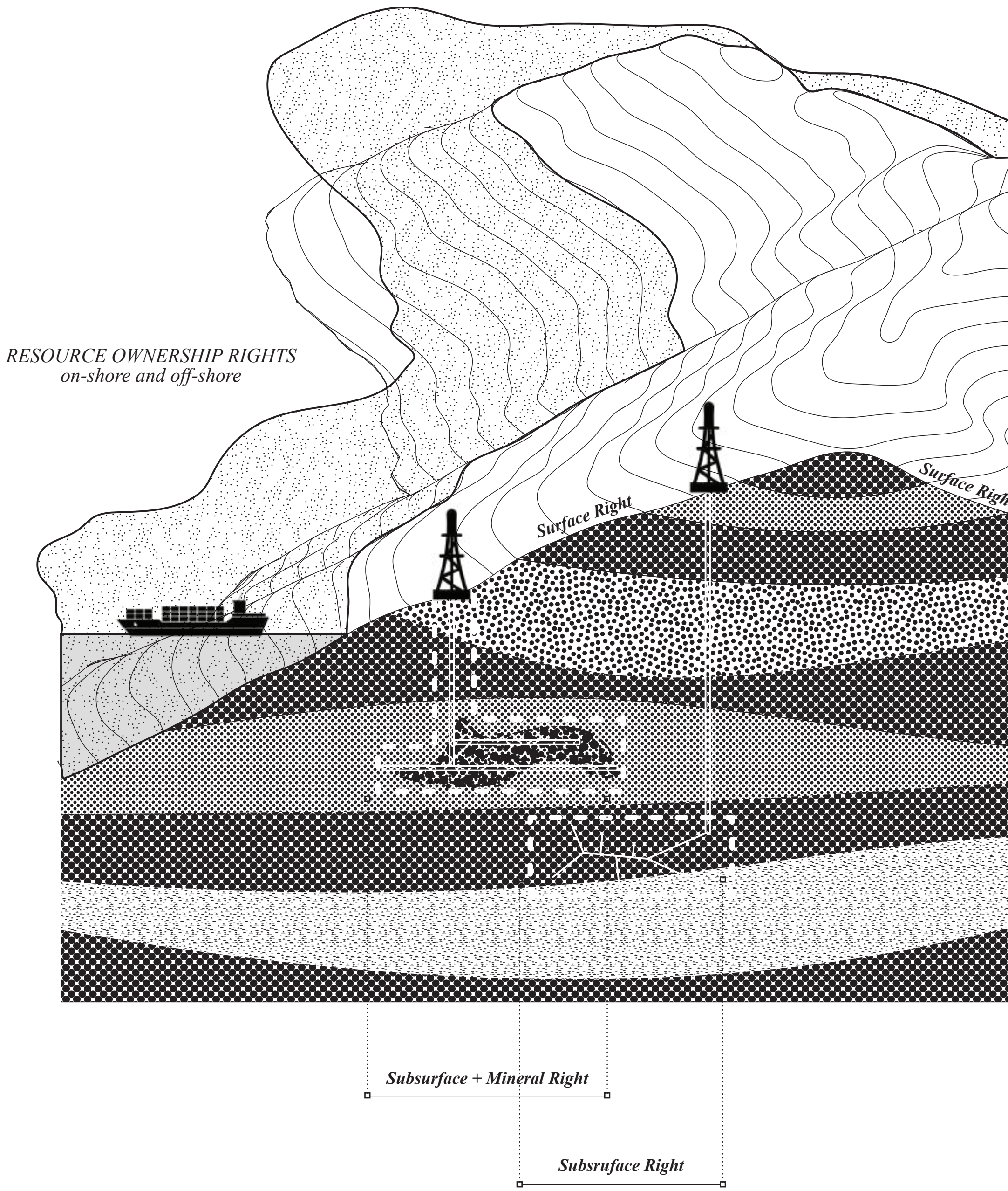
As the United States kept expanding westward and train tracks became the backbone of supply, from raw materials to finished products, a governmental entity regulating ownership rights had to be established. In Texas, the Rail-

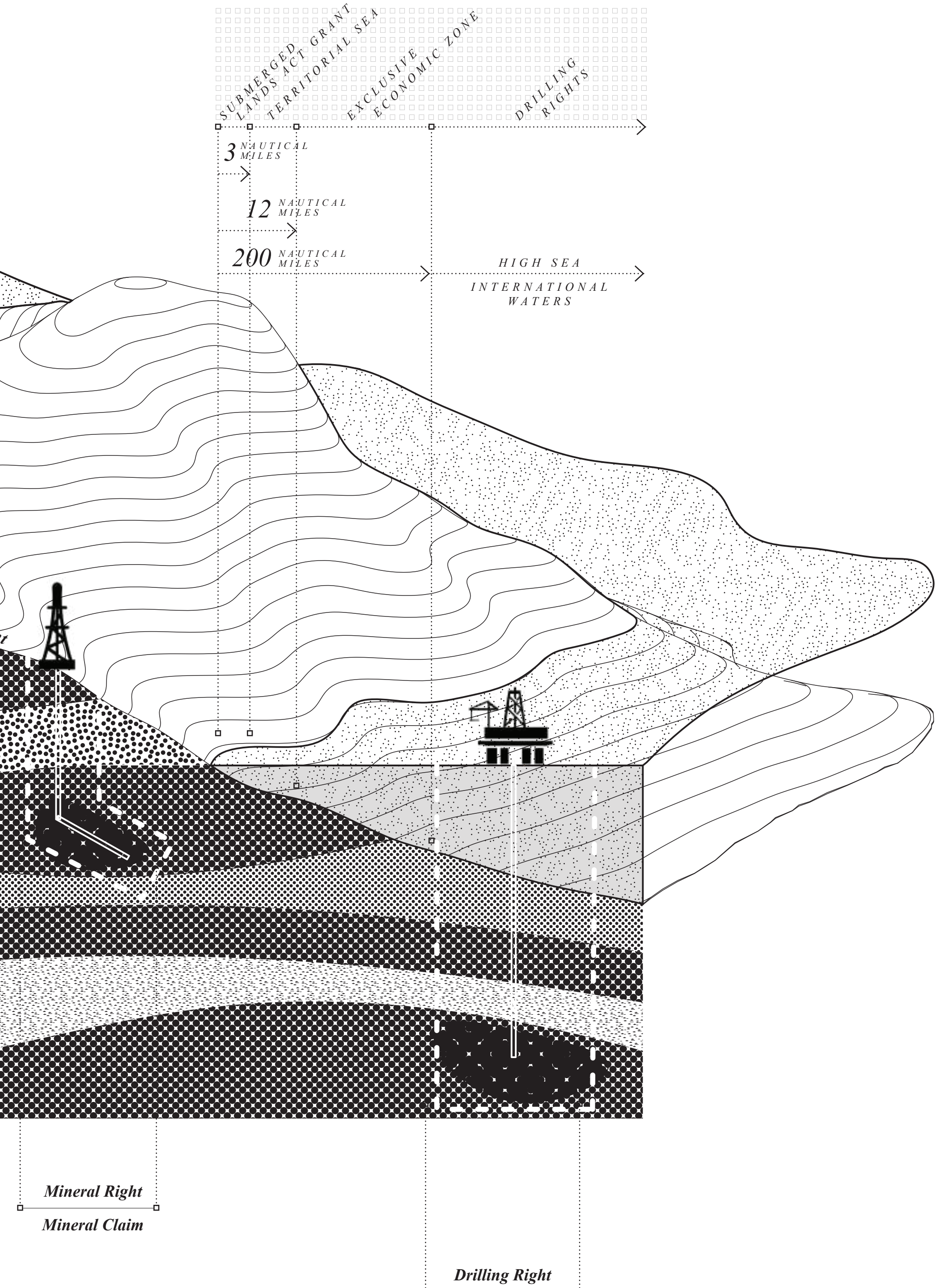
46 Cf. Ryder and Hall, "This Land Is Your Land, Maybe: A Historical Institutionalist Analysis for Contextualizing Split Estate Conflicts in US Unconventional Oil and Gas Development." pp. 149-159.

47 Cf. Corbitt Jr, "The Federal-State Offshore Oil Dispute."

48 Cf. NOAA, "Law of the Sea Convention."

Figure 14. Ownership of subsurface, mineral, and drilling rights (content appropriated from DOI, “Ownership.”).




SUBMERGED LANDS ACT GRANT
TERRITORIAL SEA
EXCLUSIVE ECONOMIC ZONE
DRILLING RIGHTS
3 NAUTICAL MILES
12 NAUTICAL MILES
200 NAUTICAL MILES
HIGH SEA
INTERNATIONAL WATERS
Mineral Right
Mineral Claim
Drilling Right

road Commission was formed in 1891 to regulate certain aspects of railway development. While trains and tracks had been centrally governed in many European countries from Austria, across Germany, and France, to the United Kingdom, railway construction was conducted by private firms in the United States. The Texas Railroad Commission (RRC) used to control five branches of economic activities: (1) railroad rates and regulations, (2) transportation and production of oil, gas, and other minerals, (3) regulation of motor transportation including buses and freight trucks, (4) regulation of butane and propane gases for public consumption, and (5) regulation of gas utility companies.[49] After World War I, control of railroad development moved gradually away from the respective commissions and fell under federal law.[50] Over the term of a century, the Texas RRC ceased all regulatory authority of railroads in Texas and has become exclusively focused on the oil and gas industry, general safety within the petrochemical industry and pipelines, and surface mining of coal and uranium.[51]

As the railways had started to cut through the landscape as the premise for the foundation of many towns along the tracks, the ownership of land and mineral rights began to mandate a spatial correlation between land, resources, and the distribution of power and wealth. With many towns developing along the rail network, the logistics landscapes and the urban landscapes of settlement started to intertwine into one integrated system. Pier Vittorio Aureli describes architecture as a manifestation of political conflict.[52]

> *"[...] the city emerges as a locus of a permanent political conflict of which architectural form is one of the most extreme and radical manifestations."*[53]
>
> > *PIER VITTORIO AURELI: THE CITY AS POLITICAL FORM, 2011*

49 See Norvell, “The Railroad Commission of Texas: Its Origin and History.” pp. 465–480.

50 Cf. Childs, The Texas Railroad Commission: Understanding Regulation in America to the Mid-Twentieth Century. pp. 3-7

51 See RRC, “Texas Railroad Commission.”

52 Cf. Aureli, “City as Political Form: Four Archetypes of Urban Transformation.” pp. 32-37.

53 Ibid.

Following Aureli's thought, these new towns in America's frontier became physical manifestations of a new regime of political form. The typology of cities along the tracks is directly linked to the rapid growth of the United States in the 20th century, as their strategic location and morphology were integral components of the logistics landscape of domestic and international trade in the emerging age of an exponentially growing global market.

2.c.
BECOMING A SPATIAL REGIME: (TRANS)FORMING URBANIZATION PATTERNS

Long before the exploration of offshore oil deposits became technologically possible and economically feasible, ocean access enabled the logistical distribution of oil to the colonial and later global markets. The process of globalization has been ongoing for almost as long as humans appeared on earth, at least in some ways. In pre-industrial times reaching back to antiquity, precious goods and spices were transported on commercial roads. The Silk Road has connected Asia and Europe as a trade corridor for spices ever since the first century BC. Alongside the rise of Islam in the seventh century, spice roads started to become a crucial infrastructural element for Muslim merchants from the Middle East and beyond. When the Age of Discovery enabled sea-bound trade connecting East and West starting in the 15th century, humankind came a big step closer to a global market exchanging spices, Seeds, metals, and other regionally occurring goods. Ultimately, however, modern globalization goes hand in hand with the industrial revolution. With steam-powered ships and trains, extensive logistical networks conquered water and land to pave the way for an international trade market.[54]

54 Cf. World Economic Forum, “A Brief History of Globalization.”

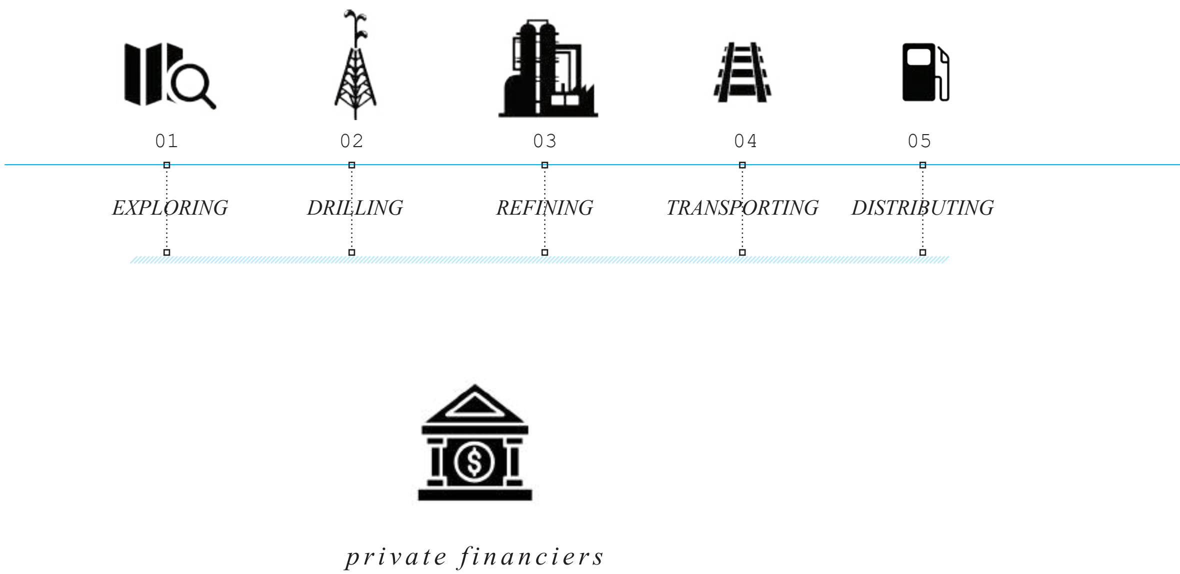
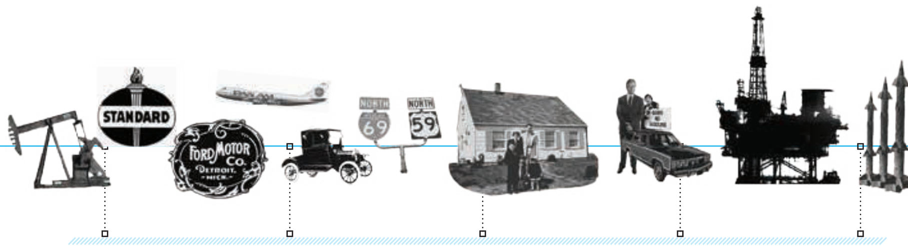


Figure 15. Oil operations divided into (1) exploring, (2) drilling, (3) refining, (4) transporting,

The British East India Company and the Dutch East India Company were early-stage multinational corporations established in the emerging 1600s. And while these two companies remained to be the largest internationally operating business entities in the centuries of Colonialism, resource-based trade fueled by industrial progress, soon became a symbol of a new world order.[55] With the fall of empires and monarchies and the rise of democracies in Europe and North America, privately-owned companies were ready to establish multinational operations. Despite the retreat of colonial influence, oil companies started to take control of reservoirs abroad, stretching from the

55 Cf. Lawson, The East India Company: A History. pp. 1-17.



governmental subsidies

and (5) distributing fossil fuels. Logistical operations in the fossil fuel industry can be publicly or privately financed, or rely on governmental subsidies.

Persian Gulf to Sumatra and from Pittsburgh to Austrian Galicia (a region in southeast Poland and western Ukraine).[56]

The use of oil for various applications, from lamps to lubricating wagon wheels, goes back for centuries. With a growing global population in the Industrial Age, the demand for oil lamps increased rapidly. Then powered by whale oil, the overfishing of whales limited the whale population around 1850 so much that alternative fuels were needed. The channel coal product kerosene replaced whale oil with refining plants being built in the northeastern United States. Around the same time, oil had been found in Pennsylvania and

56 See Tarbell, The History of the Standard Oil Company (2 Volumes in 1). pp. 25-34

Figure 16. William Harvey Corbett's 'City of the Future' from 1913 shows hoe movement through the city as a a spatial process utilizes a variety of different types of movement. (Diagram appropriated from Corbett, “Up with the Skyscraper.”)

Ontario, where it was successfully extracted, refined, and marketed in 1861. Arguably, these may not have been the first oil drilling sites in North America but the first commercially operating petrochemical undertakings.[57]

The branches of the petrochemical industry reach from (1) exploring, (2) drilling, (3) refining, (4) transporting, to (5) distributing fossil fuels. This process takes time and especially money upfront, as exploration undertakings may or may not be successful. In addition, land leases, the infrastructure for oil drilling, and the distribution network require powerful financiers funding each step until profits are produced. Among the most influential banking houses of the early days of industrial oil production were the Mellon Family of Pittsburgh in the United States, the Deutsche Bank in Berlin, and the Rothschild's in Paris.[58]

57 Cf. Tait Jr, The Wildcatters: An Informal History of Oil-Hunting in America. pp. 10-45
58 See Mitchell, Carbon Democracy: Political Power in the Age of Oil. p. 46

John D. Rockefeller's Standard Oil was among the early multinational corporations starting in 1875. First founded as an oil refining company, Standard Oil quickly evolved into a globally operating business. Yet, Standard Oil did not stop at the refining market and developed a monopoly within the refining, pipeline, and shipping branches. The early days of industrialized oil production go hand in hand with the rise of privately-owned multinational corporations providing unprecedented amounts of money and power to their key shareholders. While the origins of the oil industry were in private hands in the United States, European oil explorations started as a semi-governmental undertaking.[59] The United Kingdom first struck oil in the Middle East in the City of Masjed Soleyman in Iran. Colonial power and governmental agreements, paying marginal fees to locals, provided access to European and American companies to Middle Eastern oil. During the oil-rush at the beginning 20th century, the so-called "Seven Sisters" of petroleum-producing companies had been founded.[60] These Seven Sisters of oil were the Anglo-Iranian Oil Company (originally Anglo-Persian, now British Petroleum BP), Royal Dutch Shell (now Shell), Standard Oil Company of California (SoCal, now Chevron), Gulf Oil (now Chevron), Texaco (now merged into Chevron), Standard Oil Company of New Jersey (Esso, later Exxon, now ExxonMobil), and Standard Oil Company of New York (Socony, later Mobil, now part of ExxonMobil).[61]

As technology advanced and more oil deposits were found, new inventions started to fuel the hunger for liquid hydrocarbons. Amidst the transition from the First to the Second Industrial Revolution, Henry Ford's assembly line radically changed car manufacturing processes. With the Model-T entering the market in 1908 out of Detroit, Michigan, the gasoline-powered internal combustion engine accelerated automobile-sales at affordable prices for the masses.[62] Ford developed innovations beyond the automobiles themselves, from the production processes to labor conditions and salaries. In 1914,

59 Cf. Dixon, “The Growth of Competition among the Standard Oil Companies in the United States, 1911–1961.” pp. 1-29.

60 Cf. Beck, “The Anglo-Persian Oil Dispute 1932-33.” pp. 123-151.

61 Cf. Wood, Mason, and Finnoff, “OPEC, the Seven Sisters, and Oil Market Dominance: An Evolutionary Game Theory and Agent-Based Modeling Approach.” pp. 66-78.

62 See Laird and Sherratt, “The Economics of Evolution: Henry Ford and the Model T.” pp. 3-9.

the Ford Motor Company doubled the hourly wages of workers to $5 and decreased the work-day from nine to eight hours.[63] As unions kept forming and new inventions had started to re-shape the industrial labor market, the availability of a transportable energy source at affordable cost made lasting impacts on the urbanization patterns of 20th-century America. From the electrification of households to cars, ships, and planes to pharmaceuticals and the mass-production of oil-based products like plastics, the petrochemical industry started to impact almost every facet of everyday-life. During this time of emerging industries, new infrastructural components were needed. While the railroad network kept expanding cross-country, automobiles now also needed their own road-network. As car-sales increased, gas-stations were built, and a new level of prosperity struck through the lands, it seemed to be the next logical step to design and build a comprehensive highway network.

The Federal Aid Road Act of 1916 and the Federal Aid Highway Act of 1921 paved the way for a National Highway System for cross-country travel in the United States. During the 1930s and 40s, the foundation for the intensive network of interstate highways was laid, shaping the transportation geography in between cities.[64] It took about two additional decades to finalize the Federal Aid Highway Act of 1956 under President Eisenhower, building upon the then-existing freeways to construct the National System of Interstate and Defense Highways.[65] The government had decided to fund the construction of the highway system directly through the Federal Highway Trust Fund, which tied the motor fuel tax to highway construction. Booming fuel consumption would deliver sufficient funding given the rapidly growing number of car-owners and increasingly long distances driven.[66] Oil-consumers paid for "*freeways*." While the post-World-War II years accelerated oil consumption in response to automobiles and road construction, oil played a crucial role during the periods of war themselves. The availability of oil and gasoline paired with road construction and affordable cars was a major driver of making the burn-

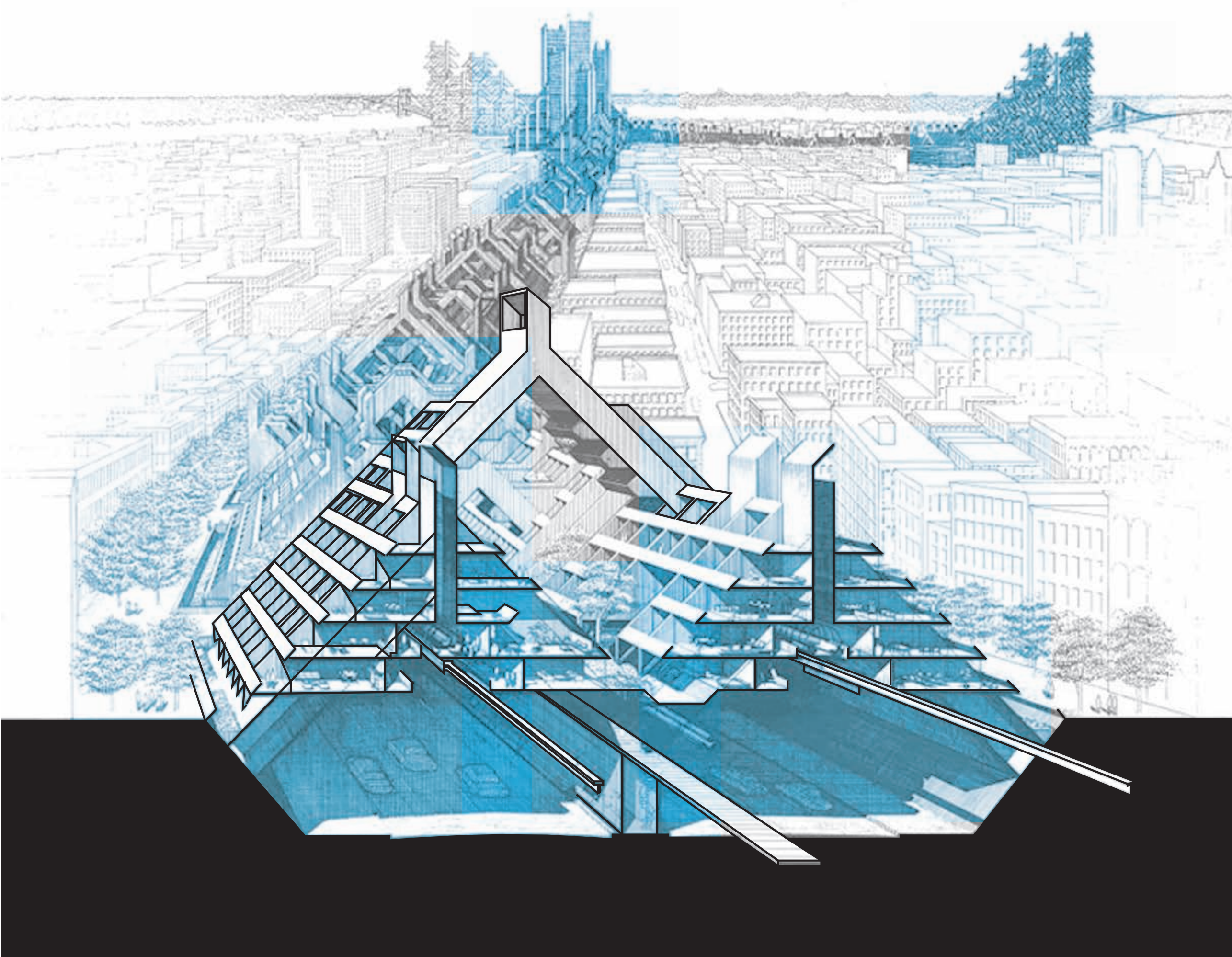
63 See Brooke, Ford Model T: The Car That Put the World on Wheels.

64 Cf. Weber, “The Evolving Interstate Highway System and the Changing Geography of the United States.” pp. 70-86.

65 Ibid.

66 Cf. McDaniel and Coley, “History of the Highway Trust Fund.” pp. 8-14.

Figure 17. Paul Rudolph's proposal for the 'Lower Manhattan Expressway,' developed in 1967, aimed for a new type of urban infrastructure in the age car-oriented development: a combination of prefabricated building blocks on top of an expressway. (Diagram appropriated from MoMA, New York)



ing of fossil fuels a spatial regime. Early urban visions of the 20th century still saw movement in the city depending on public transportation. Harvey Wiley Corbett's *'City of the Future'* is an excellent example for understanding the city as a three-dimensional process, utilizing different types of movement through it.[67] Proposals like Paul Rudolph's *'Lower Manhattan Expressway'* showed the spirit of the time: a car-oriented development of urban typologies.[68] Aligned with Jevons' Paradox, the mere fact that cheap fuel was available would lead to more fuel consumption rather than efficiency. As new car models grew bigger over time and increased in quantity, roads and parking lots shaped cities and neighborhoods in a direct spatial correlation.[69]

The American housing shortage during and especially after the world wars urgently required solutions. In 1934, US Congress founded the Federal Housing Administration (FHA) with the goal to regulate interest rates and to insure mortgages. While governmentally developed and owned social housing projects in the emerging 20th century shaped many European cities following the Modernist movement's ideals, the urbanization patterns in the United States was a transformation of Ebenezer Howard's Garden City concept. The fundamental difference, however, was that Howard envisioned Garden Cities as collectively owned communities to prevent real estate speculation, benefiting certain individuals rather than the city as a whole. Howard also did not envision a Garden City as an agglomeration of single-use residential houses along (often) privately-owned streets without sidewalks. Neither strip-malls nor parks without any amenities were part of the concept. The American planning strategies of this era followed a *garden metropolis vision*, including some of Howard's ideals, yet largely targeting a private-developer-driven approach in constructing detached single-family housing units with a front- and backyard.[70] In 1938, the FHA published a set of guidelines titled *Planning Profitable Neighborhoods*. Within this booklet, the FHA set a series of factors to distin-

67 Cf. Corbett, “Up with the Skyscraper.”
68 Cf. Dixon, Paul Rudolph: Inspiration & Process in Architecture.
69 Cf. Brown, Morris, and Taylor, “Planning for Cars in Cities: Planners, Engineers, and Freeways in the 20th Century.”
70 Cf. Weiss, “Developing and Financing the ‘Garden Metropolis’: Urban Planning and Housing Policy in Twentieth-century America.” pp. 307-319.

guish between "*good plans*" and "*bad plans*."[71] Only for those developments following the good plan scheme, the FHA would insure mortgage rates and, therefore, deliver the most critical argument for many home-buyers when choosing a neighborhood. It was simply too risky for private developers not to follow the FHA good plan as their clientele would shrink significantly.

As cars became affordable and the energy to move them available, the subdivision of the continental United States continued along interstates and highways. Fossil fuels and, therefore, cars enabled urban sprawl spatially. It was during these early decades of the new century, that the burning of fossil fuels first started to shape (urban) landscapes. Three crucial factors enabled the large-scale spatial impact of fossil fuels that would alter human settlements from here onwards: (1) production, (2) transportation, and (3) ownership, or in other words, how we produce goods, the modes of transportation and scale of distribution, and the power associated with controlling these factors.

> *In the emerging 20th century, the burning of fossil fuels started to evolve into a spatial regime fueled by technological and societal transformations in (1) production, (2) transportation, and (3) ownership of land and minerals.*

The production of goods is linked to natural resources. These resources are stored underneath the earth's surface, grown on land, submerged in water, or might be found in the air. The natural resource landscape provides the premise for settlement in almost any corner of the planet. Charles Waldheim describes the concept of Landscape Urbanism, stressing to approach "*urbanism through the lens, or lenses, of landscape*."[72] As natural resource harvesting started to boom in all stages of the Industrial Revolution, the relationship between landscape as a resource and the urban sites of manufacturing unfolded into a complex logistical system. As oil-fueled automobiles, trains,

71 See FHA, Planning Profitable Neighborhoods.
72 See Waldheim, “Landscape as Urbanism.” pp. 2-5

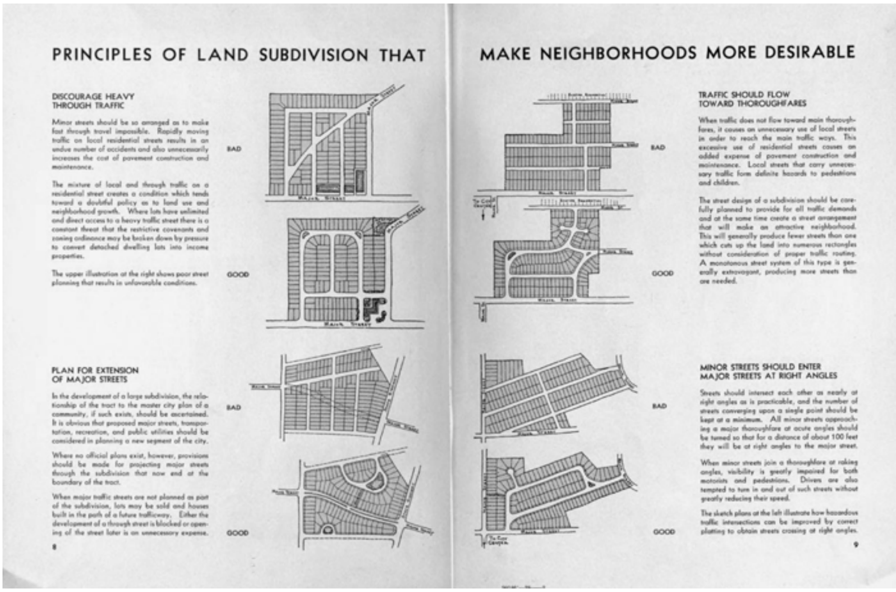


Figure 18. The Federal Housing Administration published guidelines on planning profitable neighborhoods in 1938. (Image by FHA, Planning Profitable Neighborhoods.)

ships, and airplanes and accelerated highway construction, the next level of a globalized market could develop. With the standardized shipping container introduced in 1956, goods could not just be transported faster and more efficiently, they could also change the mode of transportation from truck to train and onto sea-bound vessels.[73] This relationship between resources, manufacturing, and transportation became inherently spatial as many cities and the landscapes in between started to become part of a global logistical supply chain. As land and mineral-right-ownership direct profits to states, companies, and ultimately private individuals, the physical landscape itself evolved into a medium of social (in)justice at an unprecedented scale.

As the different stages of industrialization began to alter manufacturing and the transportation sector, the transition from wood to coal and, ultimately, to oil was essential in delivering enormous amounts of energy. Simulta-

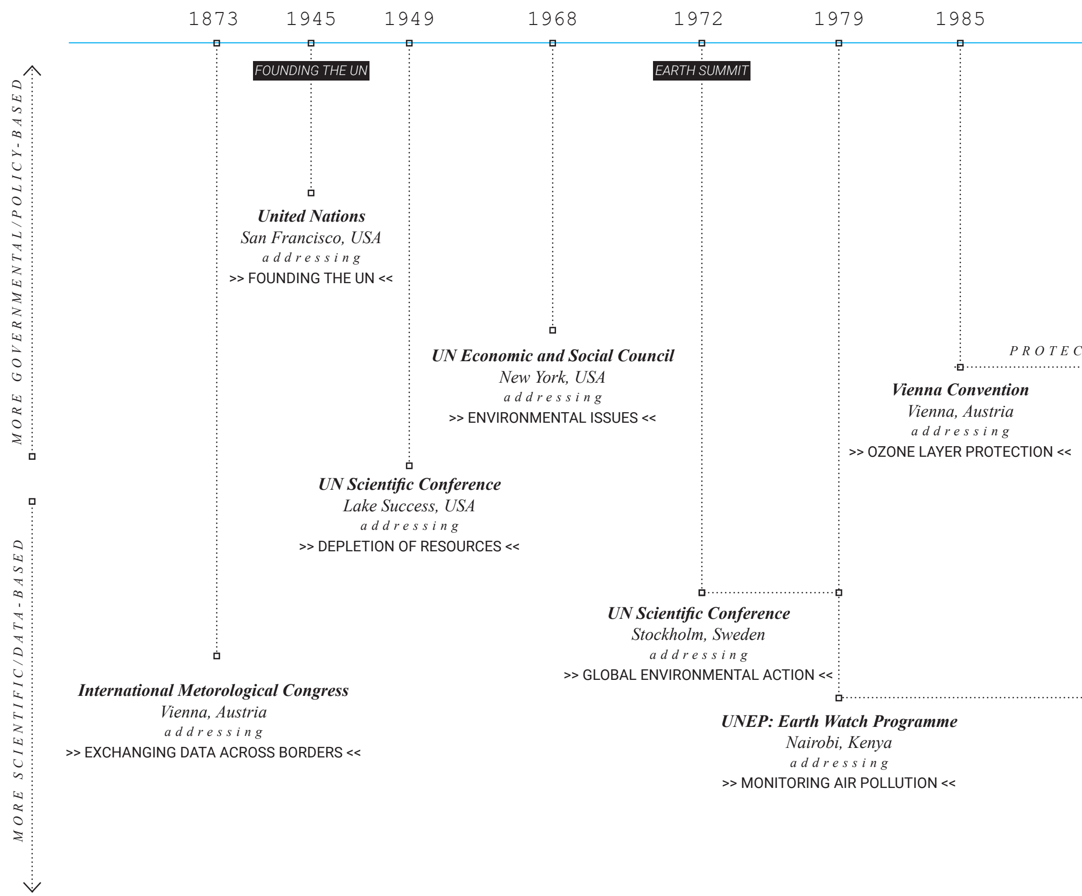
73 Ibid, pp. 69-73

neously, the fall of empires and monarchies and rise of democracies shifted resource-based wealth to individuals. Even a detour through the fascist era and two world-wars could not stop the evolving process of democratizing the Western World. To ensure the stability of nations in the process of building a democratic society, a stable or growing economy is crucial. For centuries, the value of currencies has been tied to natural resources. First silver, then gold or bimetallic reserves had set the national standards before the international gold standard regulated currency values from 1880-1914.[74] However, the two world wars and the interwar period shifted the global economy towards a new system that tied currencies to the US Dollar as a symbolic gold standard. The Bretton Woods System prevailed for decades as the post-world-war global market economy took shape.[75] This new gold dollar standard aimed to regulate private banks from currency speculation tying the value of money to the exchange of goods. Yet, as Timothy Mitchell (2011) argues, the Bretton Woods System tied the currency values not to the general flow of goods but instead to the flow of oil, enabling the *"postwar financial regime"* including the International Monetary Fund, the World Bank, and the United Nations.[76] With rapidly growing oil production, supply and demand increased. Oil fields in the United States, Mexico, Venezuela, and the Middle East contributed to the global oil market, mostly traded in US Dollars. In the 1960s, Iran, Iraq, Kuwait, Saudi Arabia and Venezuela founded the Organization of the Petroleum Exporting Countries (OPEC) as an intergovernmental organization with the goal of unifying petroleum policies among the member countries.[77]

The turbulent decade of the 1970s highlighted the downsides of oil-dependency in every-day life. With long lines of cars waiting at gas stations across the United States, the geopolitical regime of oil had arrived in the city.[78] Moreover, the 1973 oil embargo did not just disrupt the energy market and create shortages, it also played a key role in some still ongoing conflicts in the Mid-

74 Cf. Eichengreen and Flandreau, The Gold Standard in Theory and History. pp. 2-5
75 Ibid., 7-9
76 See Mitchell, Carbon Democracy: Political Power in the Age of Oil. pp. 109-111
77 See OPEC, “History.”
78 Cf. Office of the Historian, “Oil Embargo, 1973–1974.”

Figure 19. Timeline of major events acknowledging Climate Change by the United Nations. (Data source: United Nations)



In 1988, Climate Change was acknowledged by the United Nations.

In 1989, several global environmental initiatives were started.

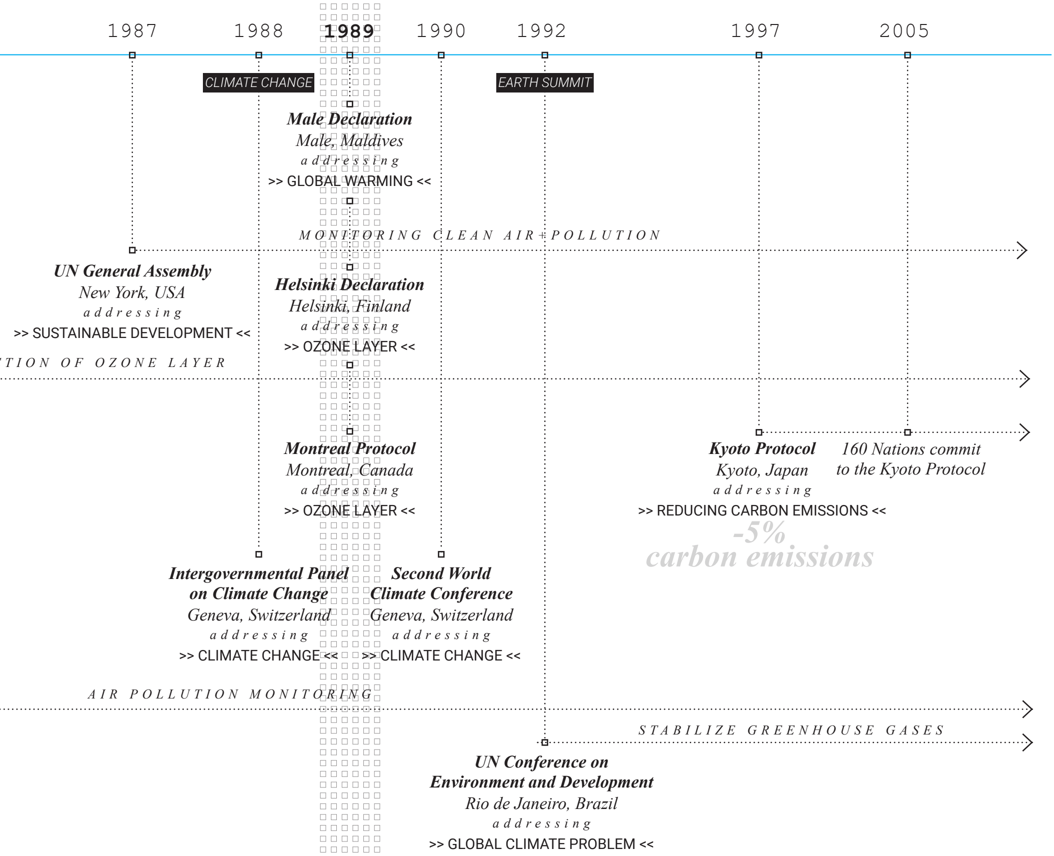
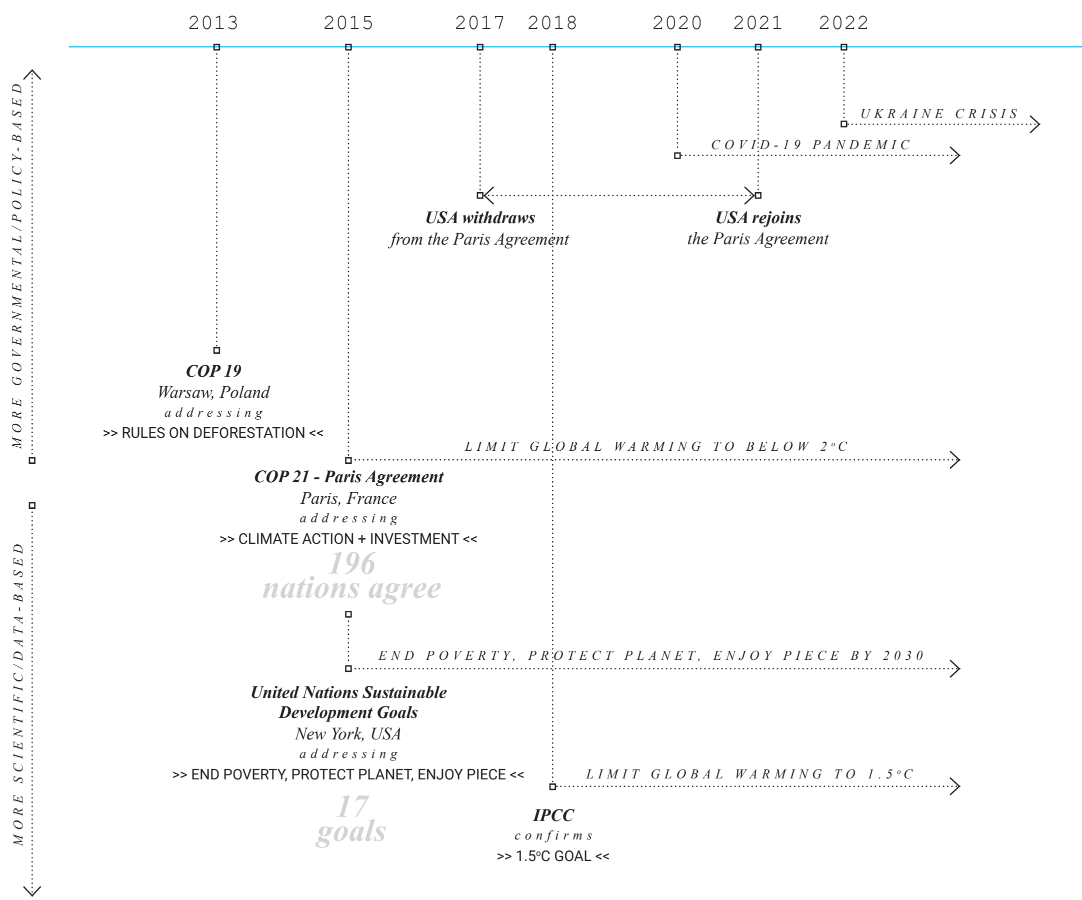


Figure 19 continued.



dle East.[79] Going back to 1945, with the formation of the United Nations in San Francisco, an international organization started to become a mediator for the nations of the world. In 1949, only four years after its formation, the UN addressed resource depletion as a topic at the Scientific Conference in Lake Success. In the 1960s and 70s, environmental issues and global environmental actions took shape. In 1985, attempts to protect the ozone layer began and the term *"sustainable development"* was adopted only two years later. The 1980s were a crucial decade in identifying, understanding, and acknowledging anthropogenic climate change in response to greenhouse emissions that lead to global warming. The UN formally acknowledged these issues in 1988 and 1989. In the following decades, numerous resolutions and strategies were developed from the Kyoto Protocol in 1997 to the COP21 (Conference of the Parties) Paris Agreement of 2015.[80]

-1.5°C goal

Over the past 200 years, industrialized processes and mass production, new modes of transportation, and the subdivision of lands and minerals into private ownership have altered the way humankind utilizes and interacts within (urban) space.[81] The fossil-fuel-powered car enabled the typology of suburbs as the prevalent urbanization pattern in the United States. The direct or indirect impact of oil on urbanization patterns took place in a variety of ways, from codes and regulations, to auto-oriented town planning, to organizations with powerful lobbies impacting governments and decision-makers. In the years after 1955, the Humanities Office of the Rockefeller Foundation initiated its own Research Program for Urban Design Studies focusing on urban theories in the disciplines of architecture, city planning, and landscape design. Several highly influential books and projects in the field of urban history, theory, and criticism were funded by the Rockefeller Foundation, including Jane Jacobs's *The Death and Life of Great American Cities* in 1961, and other important works reaching from Kevin Lynch to Christopher Alexander.[82]

There is no doubt that along the lengthy process, from exploring across re-

79 Ibid.
80 See UN, "History of the United Nations."
81 Cf. Hein, "Oil Spaces: The Global Petroleumscape in the Rotterdam/The Hague Area."
82 Cf. Laurence, "The Death and Life of Urban Design: Jane Jacobs, The Rockefeller Foundation and the New Research in Urbanism, 1955–1965." pp. 145-172.

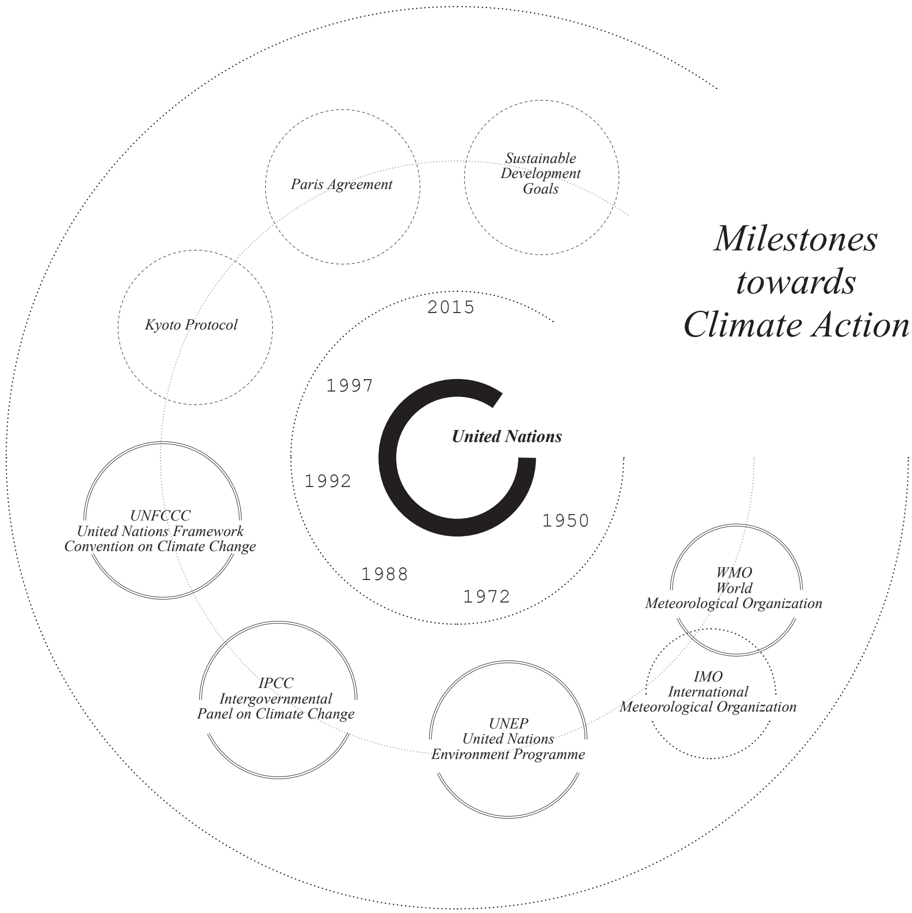


Figure 20. Milestones towards global climate action. (Data source: United Nations)

fining to the various applications of petrochemicals in mass-products, oil has been impacting almost every branch of human life. Profits, wages, taxes, and numerous inventions have contributed to the growing standard of life in the 20th and 21st centuries, especially in developed countries. There is also no doubt that fossil fuels have altered the built environment and shaped the development of cities and landscapes. From built infrastructure to changing the way we transport goods, communicate, or insulate, heat and cool buildings. There should, however, also be no doubt about the devastating repercussions that decades of fossil-fuel-burning have brought to the planet.

As a spatial regime, the burning of fossil fuels still performs as a macro-level process impacting the natural, cultural, and built environment over time. Oil remains to be a socio-economic, and political driver of spatial (trans)formation. Zooming into specific regions where primary economic sectors of resource extraction are still the most significant branch of local production, the State of Texas and especially the Texas Coast outperform many global competitors. Given the volume of petrochemical products being extracted, refined, and shipped out into the world, cities along the Texas Coast are embedded into a geopolitical territory of petrochemical production and logistics. To identify how the burning of fossil fuels as a spatial regime impacts urban landscapes beyond the general consumer, the unique type of coastal oil towns in Texas represents an ideal case-study.

03

Urban Landscapes of Oil

(re)Constructing
a new Type of City

03

Urban Scale

URBAN LANDSCAPES OF OIL

(re)Constructing
a new Type of City

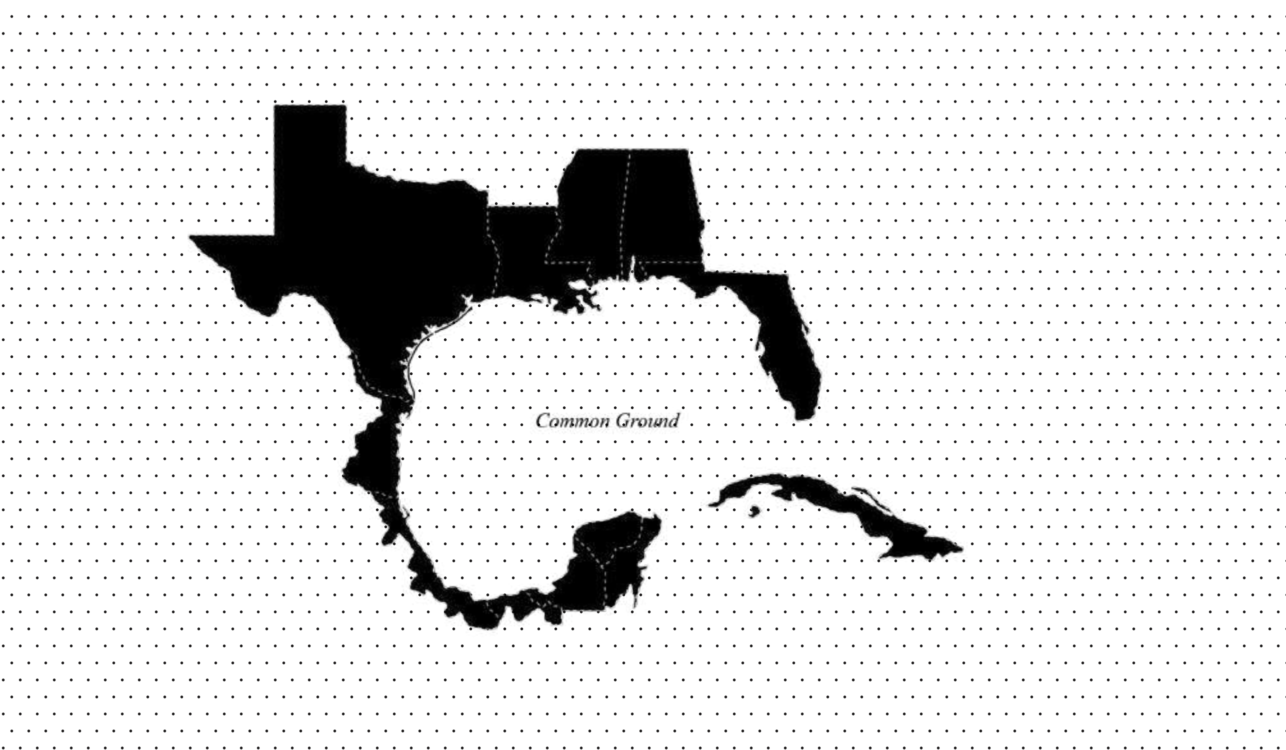
The spatial regime of burning fossil fuels has altered the atmosphere. Now, weather, water, and landscape are responding, changing urban ecosystems as a premise for settlement. The Gulf of Mexico as common ground between Mexico, Cuba, and the United States, is a geopolitical territory, producing, refining, and supplying the globe with oil and gas. Cities along the Texas Coast are at the forefront of contributing to and experiencing the repercussions of anthropogenic climate change. These cities serve as prototypes, defining "coastal oil towns" as urban typologies vernacular to Texas. Spread across four urban clusters between Louisiana and Mexico, these new types of territorial cities have developed around the economic power of oil. Landscape, fauna and flora, water supply, ocean access, and the socio-economic context served as a premise for this particular type of urbanization pattern. As the repercussions of climate change materialize, both architecture and the city need to respond to the changing environmental conditions.[1]

1 Parts of this chapter were published online in Jenewein, "The Texas Coast as Geopolitical Territory: The Spatial Regime of Burning Fossil Fuels in Coastal Landscapes of Oil." The author retained the copyright.

Coastal areas have always been in environmental danger zones prone to storms, flooding, and seismic activity. At the same time, strategic coastal locations allowed for early global cities to become trade hubs connecting the world.[2] River deltas and bays, as fertile regions with relatively calculable environmental risks, have brought resource-based economic growth to cities and regions along the coast and in the hinterlands. Understanding water not as a risk or boundary but as a connector of places and well of life accelerated the development of thriving settlements, towns, and even mega-cities. More than ever before, architects need to leave the object scale behind and understand architectural creation as an integral part of nature beyond the built environment. Land(scape) acts as the physical medium that ties architecture and nature together. This relationship between the (architectural) object and the ground must be renegotiated in times of (climate) change as the shifting edg-

2 Cf. Batista, "Coastal Risk." pp. 524-534.

Figure 21. The Gulf of Mexico as common ground between Mexico, Cuba, and the United States

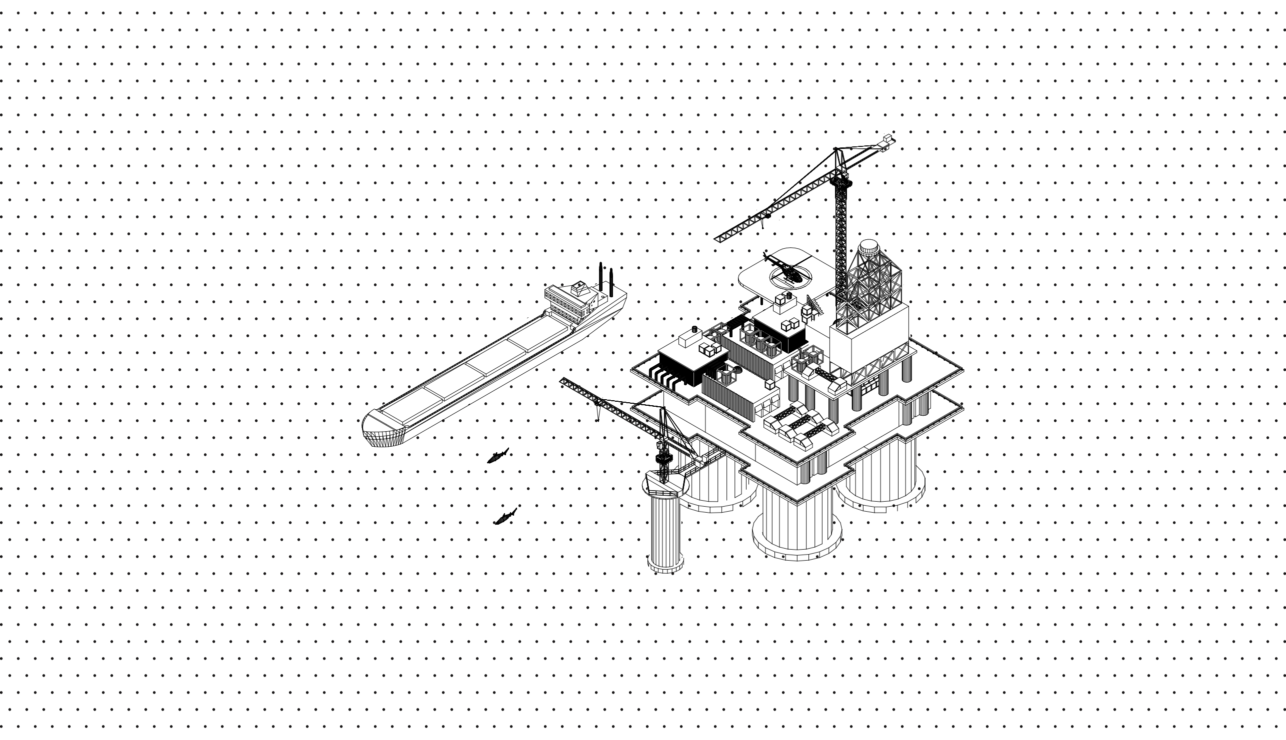


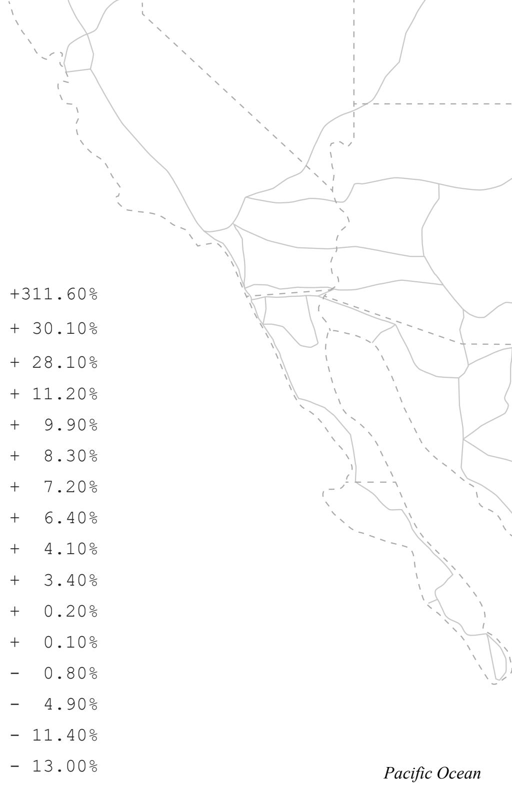
es between water and land (re)shape the (sur)face of coastal territories. After humankind had started altering the world's atmosphere over the past two centuries, the environmental repercussions of industrialization have now begun to manifest physical impacts on the natural environment. These impacts impose new parameters for architecture on the scale of both buildings and cities and the logistical infrastructure connecting them across the changing landscapes in different territories.

The Epoch of the Anthropocene,[3] this time of human activity impacting global climate, creates a new narrative of how architects and designers approach context. The ties between industrialization, capitalism, and globalization share a common denominator: fossil fuels. The burning of fossil fuels, as a symbol of carbon emissions across many economic sectors, from transportation to agriculture, has become a spatial regime demanding transforma-

3 See Crutzen, "The 'Anthropocene.'"

is a geopolitical territory of petrochemical logistics.





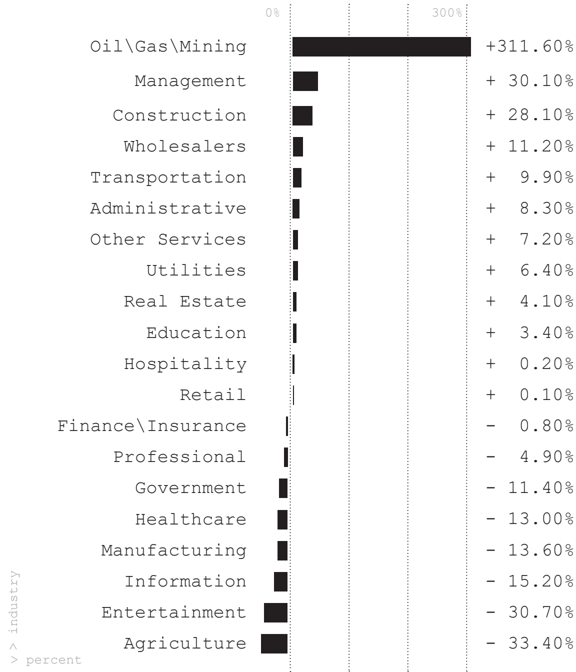


Figure 22. This chart shows the employment in various economic sectors in Texas relative to US average. (Data source Statistics-Atlas, “Industries in Texas.”)

tions of the built environment. The use of fossil fuels has not directly shaped the design of cities. Cars can be powered with alternative resources, heating and cooling systems can run on renewables, plastic can be replaced in many of its applications of everyday life. Whether a car runs on an Otto Motor or on an electrical engine, changes a city marginally. Yet, the use of gasoline as a major energy source to power millions of cars worldwide over decades is putting lives and cities at risk. The dependency on crude oil and its applications has been increasing over the past century and continues to grow. Even though Western democracies developed cities in different ways, the postwar

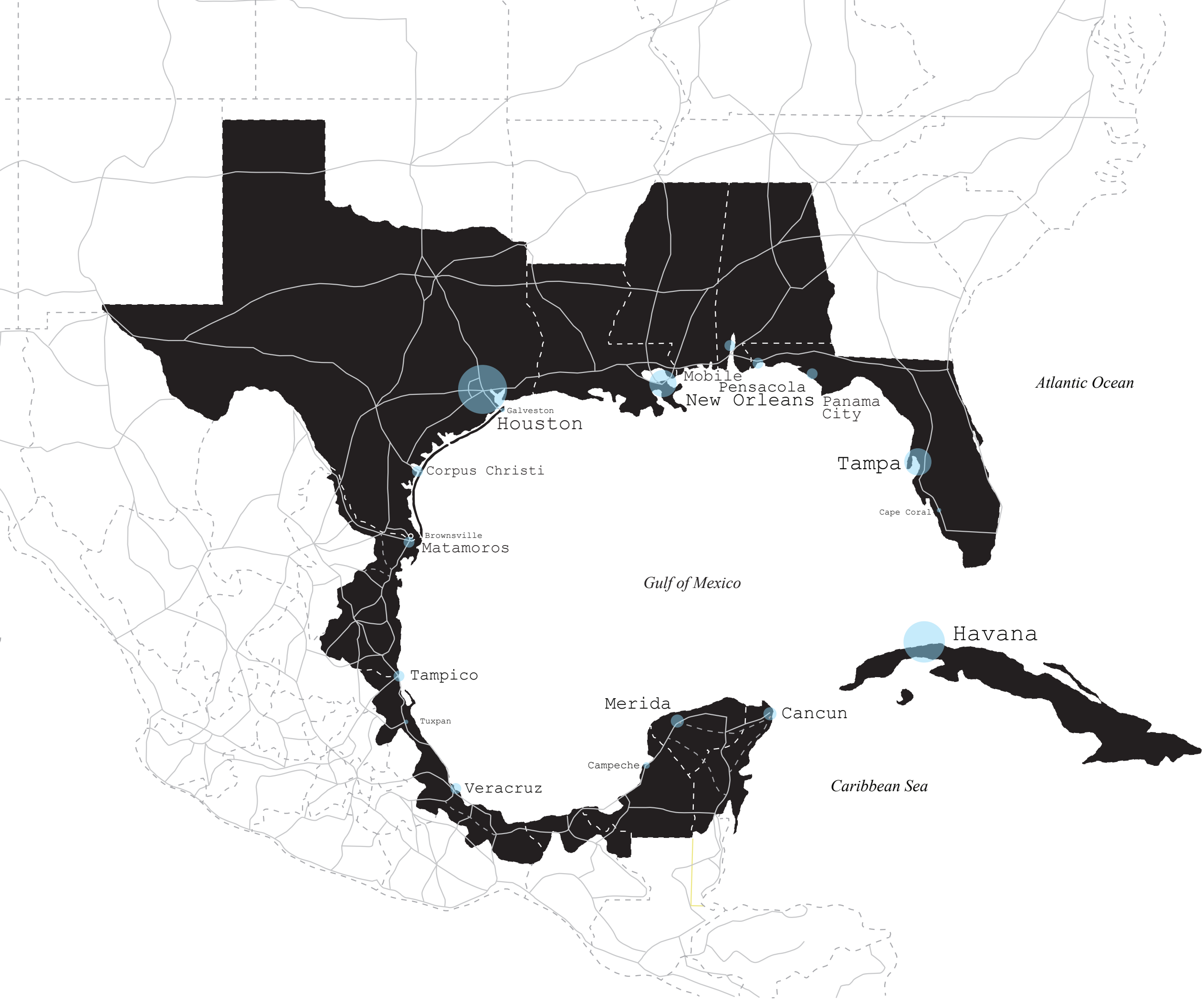
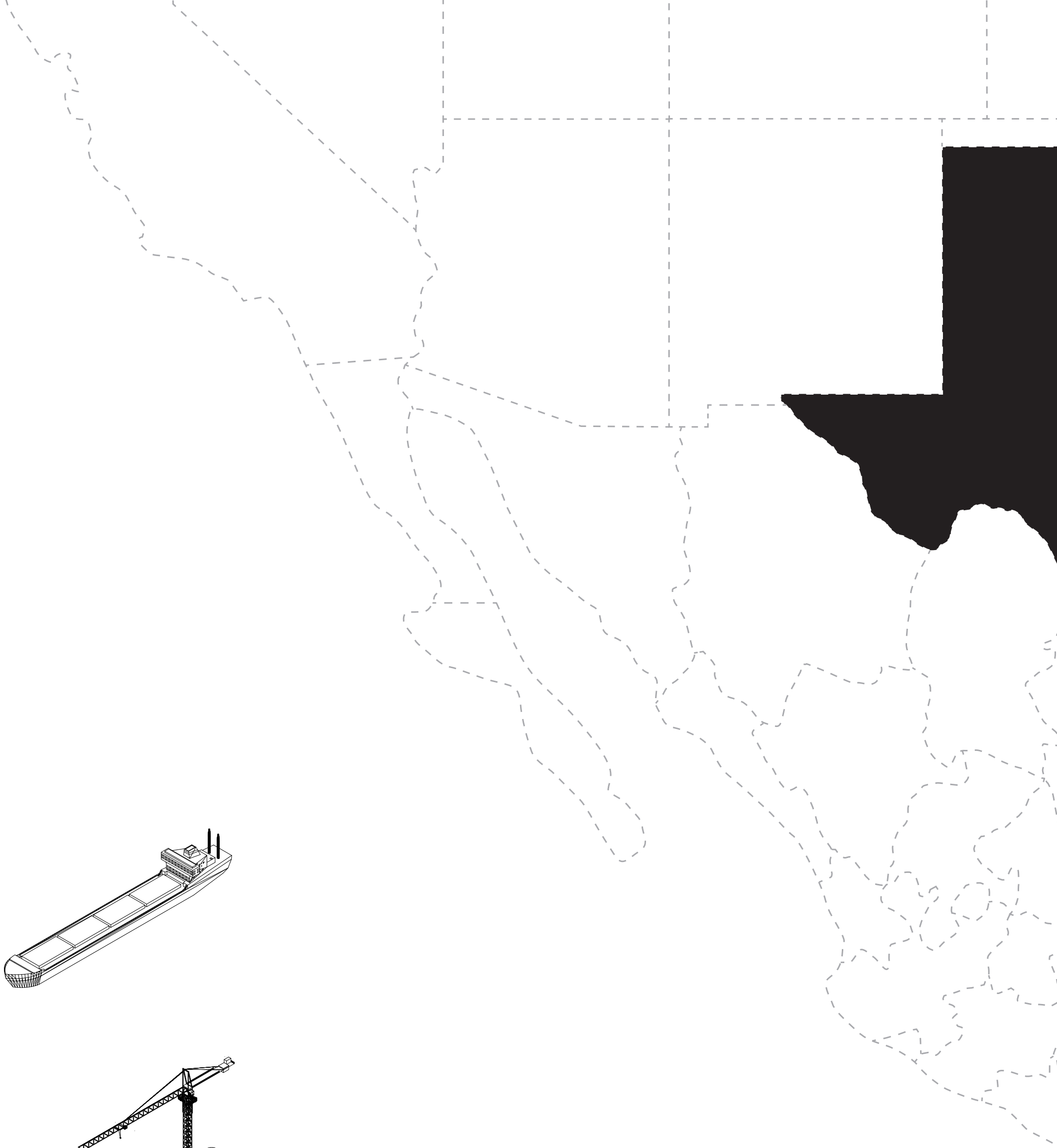
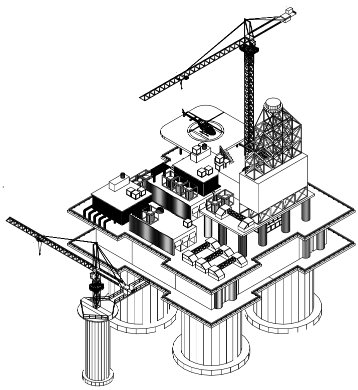


Figure 23. Largest cities along the Gulf of Mexico. The diameter of the circles indicates total urban population of the respective city. (Appropriated from Open Streetmaps, data source: Statistics-Atlas)





3,700+ permanent structures
in the US Federal Waters
of the Gulf of Mexico only

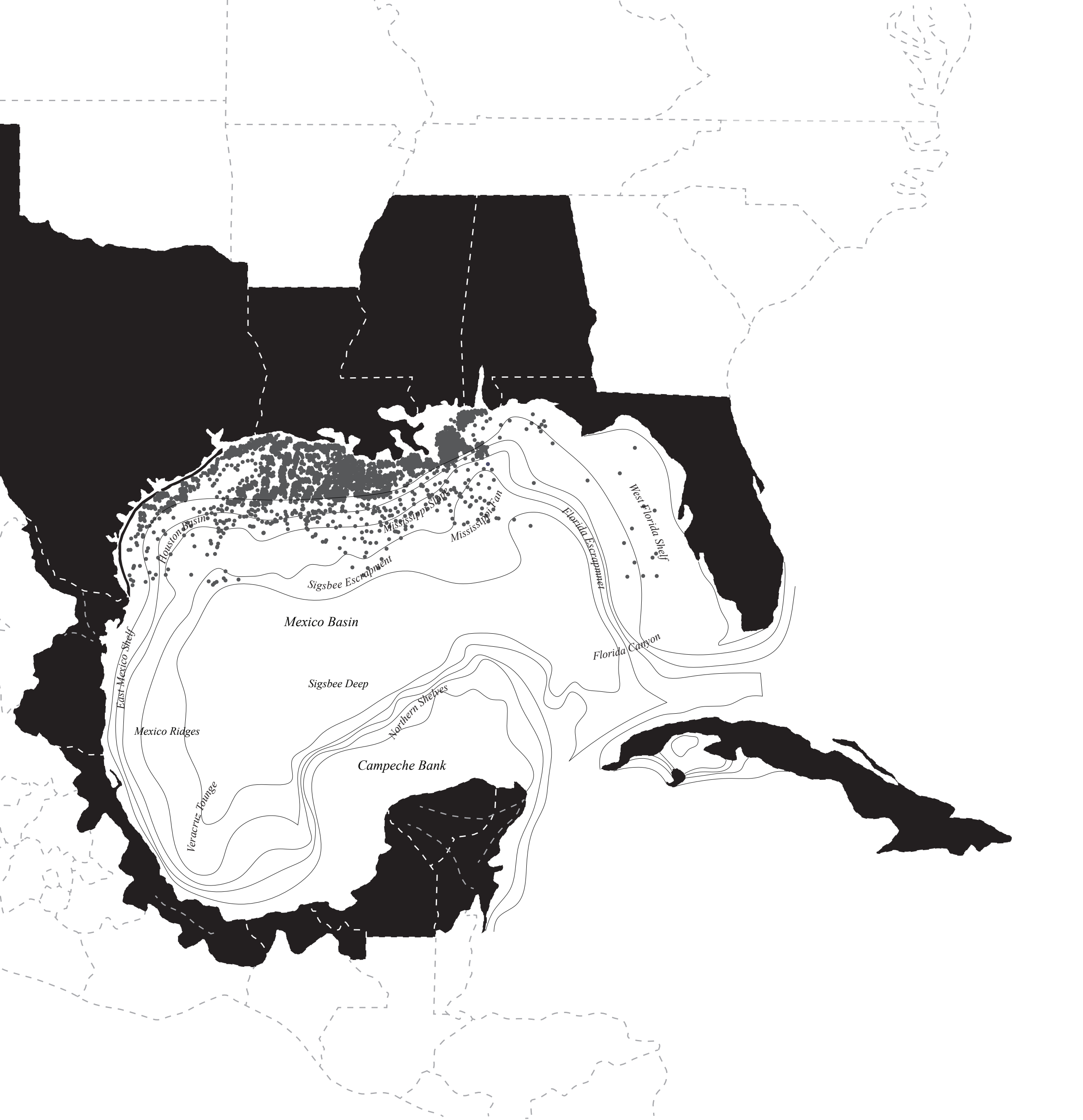


Figure 24. Offshore oil platforms in the Gulf of Mexico. The circles indicate the locations of the platforms and show a significant concentration off the coast of Louisiana. (Appropriated from Open Streetmaps)

economies on both sides of the Atlantic started to *"tie the value of money to the movement of oil"*[4] in the mid-20th century. This fact is significant, as urban morphologies, consumer demand, and wealth became connected to a commodity that, unlike land or water, cannot be used to sustain human life. Any type of natural resource harvesting leaves footprints on the planet. The drilling-oriented industry has shaped landscapes and altered coastlines to allow for heavy industry and major seaports. The question is no longer how the design of coastal cities, facing major storms and rising sea-levels, needs to evolve in response to the changing climate, but if cities along the coast should exist as a typology itself. Over thousands of years, coastal cities were able to develop thriving economies, taking advantage of access to oceans connecting the world. Now, an enormous amount of time, labor, materials and money needs to be invested to develop infrastructural typologies of a kind and scale, unseen before, to protect what can (or cannot) be protected. Besides the risk of climate change, industrial production along coastlines has caused severe ecological hazards and, at times, disasters. Major spills, contaminated soil, or toxic drinking water have shaped (urban) landscapes and impacted fragile ecologies.

> *"Port city regions are territories adjacent to large bodies of water, where a changing group of stakeholders and institutions have facilitated a spatial system for the transshipment of goods and people, often for decades or even centuries. When the interests of all stakeholders have been aligned, port city regions have emerged as strong economic, political and cultural centers of trade and travel."*[5]
>
> *> CAROLA HEIN: TOWARDS A COMPARATIVE SPATIAL ANALYSIS FOR PORT CITY REGIONS BASED ON HISTORICAL GEO-SPATIAL MAPPING, 2019*

4 Mitchell, Carbon Democracy: Political Power in the Age of Oil. p. 109

5 Hein and Van Mil, "Towards a Comparative Spatial Analysis for Port City Regions Based on Historical Geo-Spatial Mapping."

The Gulf of Mexico and the Texas Coast are prototypical territories of industrial production, heavily relying on the petrochemical industry. An oil-exploring, oil-producing, oil-refining, oil-transporting, and oil-distributing territory on land and water. Along the shoreline, several port cities have evolved within the petrochemical economy of the state. They anchor industrial activity spanning from exploring to producing, and from transporting to distributing goods globally.

As global economies shift towards the tertiary service sector, the late Texas oil-boom of 2016, accelerated by the COVID Pandemic and the Ukraine Crisis, once again shifts the regional economy along the coast towards secondary, if not primary, economic sectors, processing crude oil. In late 2015, US Congress voted to repeal the 40-year ban on crude oil exports. Advanced drilling technology enabled domestic production to double from 2009 to 2015.[6] Ever since, the United States and especially the State of Texas have restarted their global operations, exporting oil, gas, and petrochemicals. With 168,981,727 BBL (barrels) of oil and 946,619,630 MCF (thousand cubic feet) of natural gas extracted in Texas, production peaked in January 2020 right before the COVID Pandemic led to a temporary decline in production.[7] These enormous amounts of oil, gas, and hydrocarbon products are processed in the refineries in America's largest petrochemical corridor at the gateway to the Gulf of Mexico, the Atlantic, and across the seven seas.[8]

The Gulf of Mexico may be seen as common ground between Mexico, Cuba, and the United States. It connects three countries, three distinct political regimes, and three different cultures as they have evolved over time. Across political boundaries, the fragile ecosystems around the Gulf are facing similar threats both natural and human-caused. Environmental threats like hurricanes, tropical storms, wind, and flooding are native to the coastal region. The long list of hurricanes and tropical storms causing billions of damage and even lives underline the risk coastal settlements are exposed to. From the great hurricane of 1900 destroying Galveston to Celia in 1970,

6 See GAO, “Crude Oil Markets: Effects of the Repeal of the Crude Oil Export Ban.”

7 Texas Railroad Commission (2022, May) Monthly Oil & Gas Production. Retrieved See RRC, “Monthly Oil & Gas Production.”

8 See EPA, “Greenhouse Gas Reporting Program (GHGRP).”

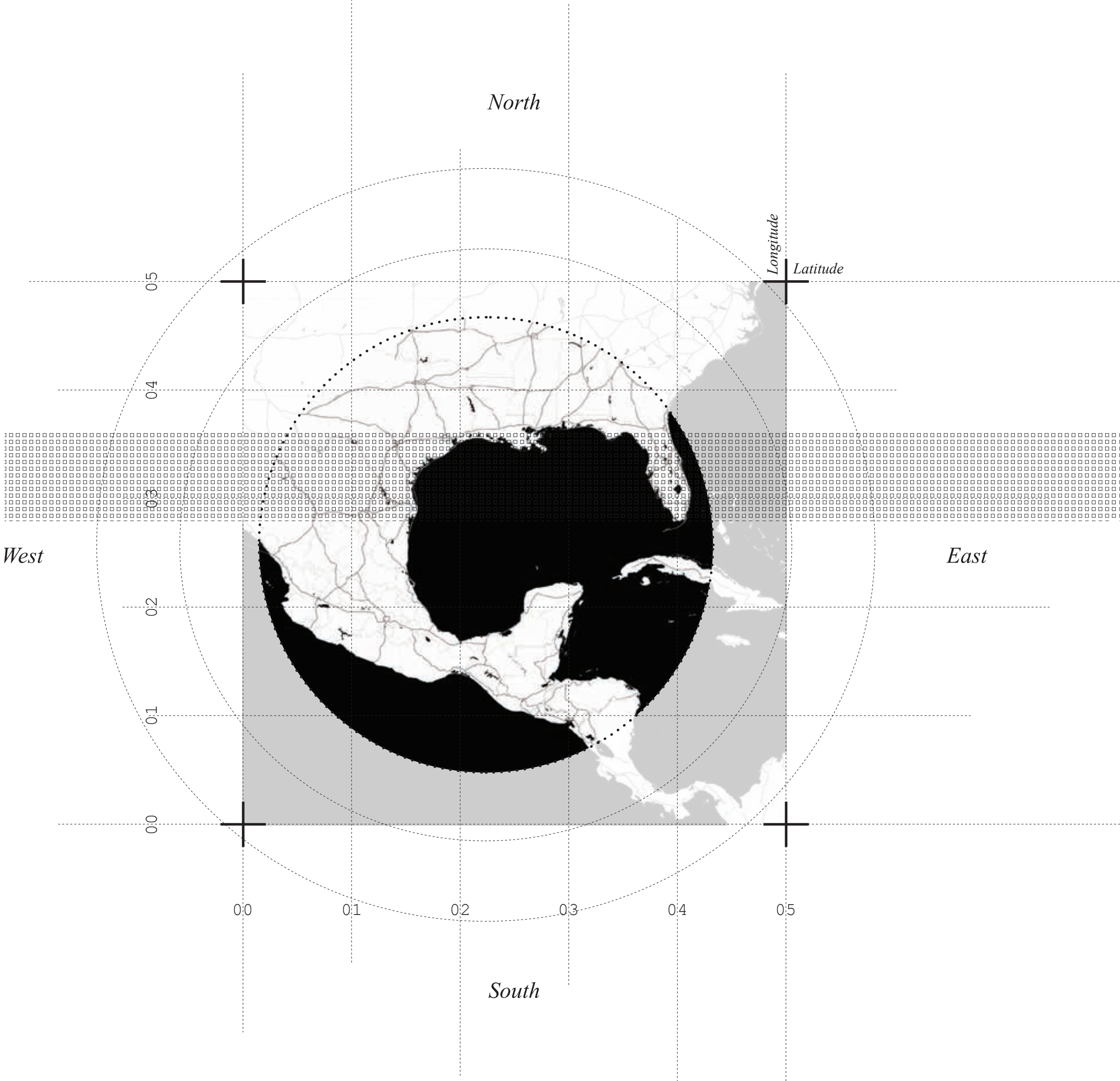
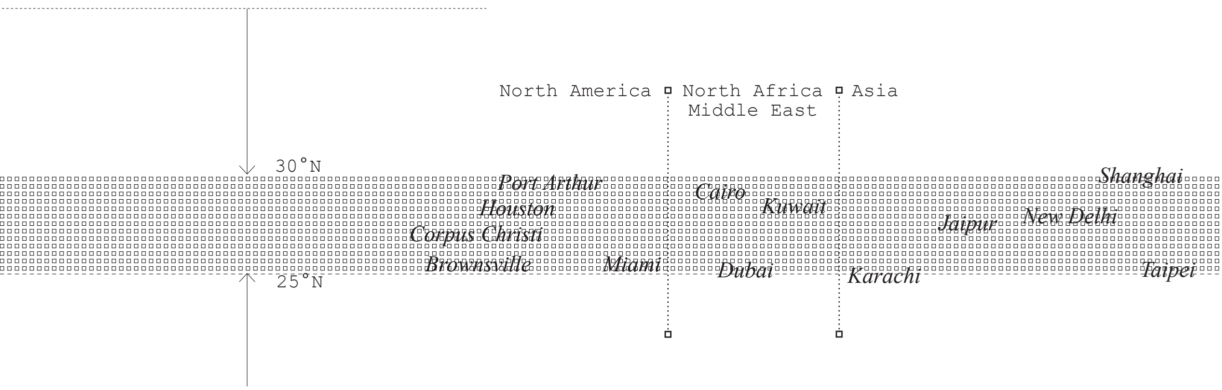


Figure 25. Location of Texas' four major petrochemical clusters along the Gulf Coast in comparison to other cities between 25-30°N.



Katrina in 2005, Harvey in 2017, or Laura in 2020, numerous storm events left devastating results.[9]

Defined as a *"large, productive, warm-water ecosystem,"*[10] the Gulf naturally protects its shorelines through salt marshes and mangroves nearly along the entire coasts of Mexico and Cuba and major parts of the US. In addition, large portions of the Texas Coast are sheltered by barrier islands. Thriving ecologies of corals, fish, and wetlands have been capable of adapting naturally to changing environmental conditions for thousands of years. The Gulf is a rich resource of life and of distinct species sharing a common habitat.[11] It provides access to both the inter-coastal waterway system, connecting the coast upstream all the way to Minneapolis, and also is a gateway to the world

9 See NOAA, "Hurricanes in History."
10 Cf. Love et al., The Gulf of Mexico Ecosystem: A Coastal & Marine Atlas. pp. 1-5
11 NPS, "Gulf Coast Network Ecosystems."

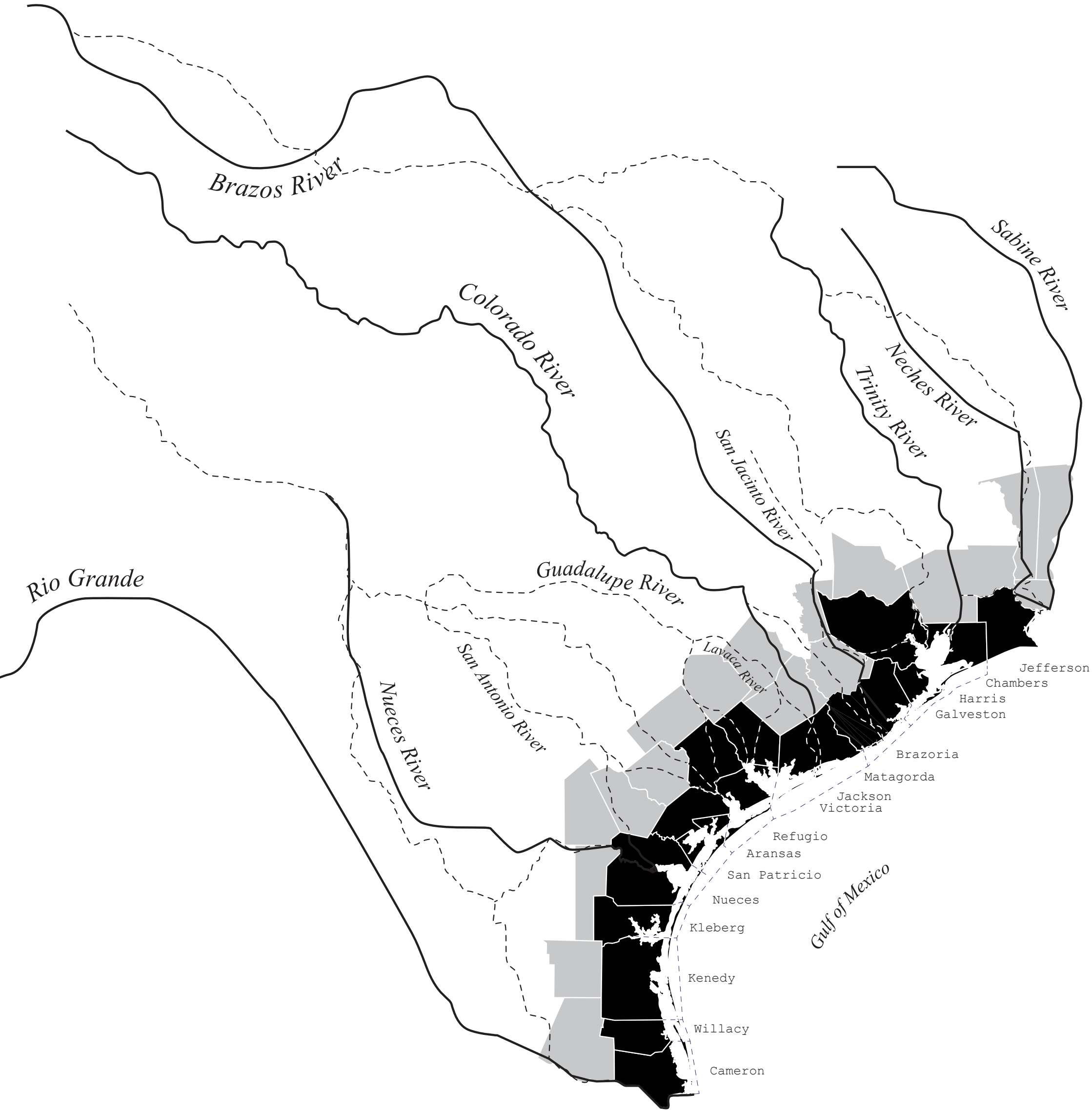


Figure 26. Major rivers, bays, and estuaries in Texas' costal counties. (Map appropriated from Open Streetmaps)

across the Atlantic or Pacific.[12] The geographical location created profitable conditions for settlement and trade within and beyond the Americas.

On the other hand, the Gulf of Mexico is a gigantic industrial field. Deeply embedded into this large body of water, are roughly 52,000+ known boreholes, 5,800+ active leases, and 3,370+ oil and gas platforms pumping in Federal Waters of the United States only. Over the past decades, the oil industry in the Gulf has moved farther offshore, now drilling in deep (>305m, 1,000ft) and ultradeep water (>1,524 m, 5,000ft).[13] The harvesting of fish and hydrocarbons has significant impacts on the regional economies of the respective countries, states and cities along the shore.

The power of oil has dictated the shape of coastal cities along the Gulf. As the oceans rise, storms increase, and temperature climbs, Texas needs to prepare for a post-oil future in a landscape soaked in petrochemicals.

3.a.
HARVESTING THE RESOURCE LANDSCAPE: (re)CLAIMING NEW TERRITORIES

The consequences of climate change on the Gulf of Mexico have become more visible in the past two decades.[14] Human-caused destruction of fauna and flora, off- and on-shore, has caused severe damage to the natural and built environment, locally, regionally, and globally.[15] Reaching back to the Maya Civilization from Yucatan to the Florida Peninsula, and to Cuba, the coastal territory around the Gulf has a long and culturally rich history. The South Texas Coast, located at Mexico's frontier, was settled by Anglo-American traders in the 1830s, though the history goes back to Spanish coloniz-

12 Cf. Love et al., The Gulf of Mexico Ecosystem: A Coastal & Marine Atlas. pp. 17-20
13 Ibid., pp. 134-137
14 Cf. USGS, "Climate and Environmental Change in the Gulf of Mexico and Caribbean."
15 See Karnauskas et al., "Ecosystem Status Report for the Gulf of Mexico." p. 52.

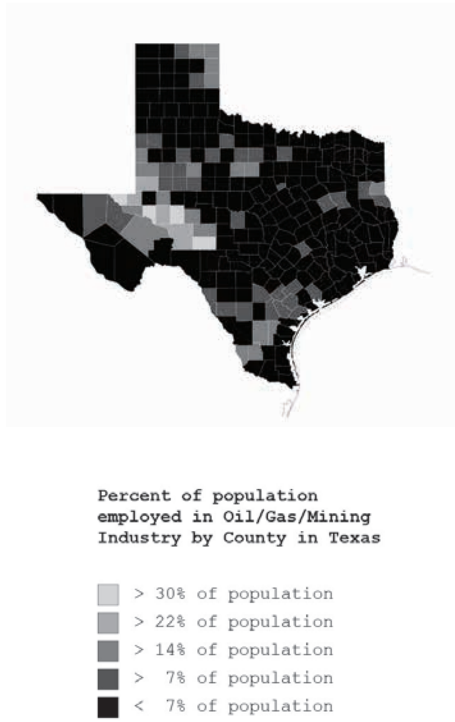


Figure 27. Pre-Covid median income in the oil/gas/mining industry in the respective counties of Texas. (Data source Statistics-Atlas, "Industries in Texas.")

Figure 28. Pre-Covid percentage of population employed in the oil/gas/mining industry in the respective counties of Texas. (Data source Statistics-Atlas, "Industries in Texas.")

ers to the mid-18th century.[16] The cities along the Texas Coast are located at the estuaries of major rivers, which provide access to the hinterlands. Beaumont-Port Arthur to the north and Corpus Christi and Brownsville to the south, are the only larger cities along the sparsely populated Texas Coast, besides the metropolitan area of Houston-Galveston. The history of these cities shows the economic transformation from pre-industrial agriculture to a globally exporting petrochemical industry at the scale of other nations rather

16 Cf. Arreola, Tejano South Texas: A Mexican American Cultural Province.

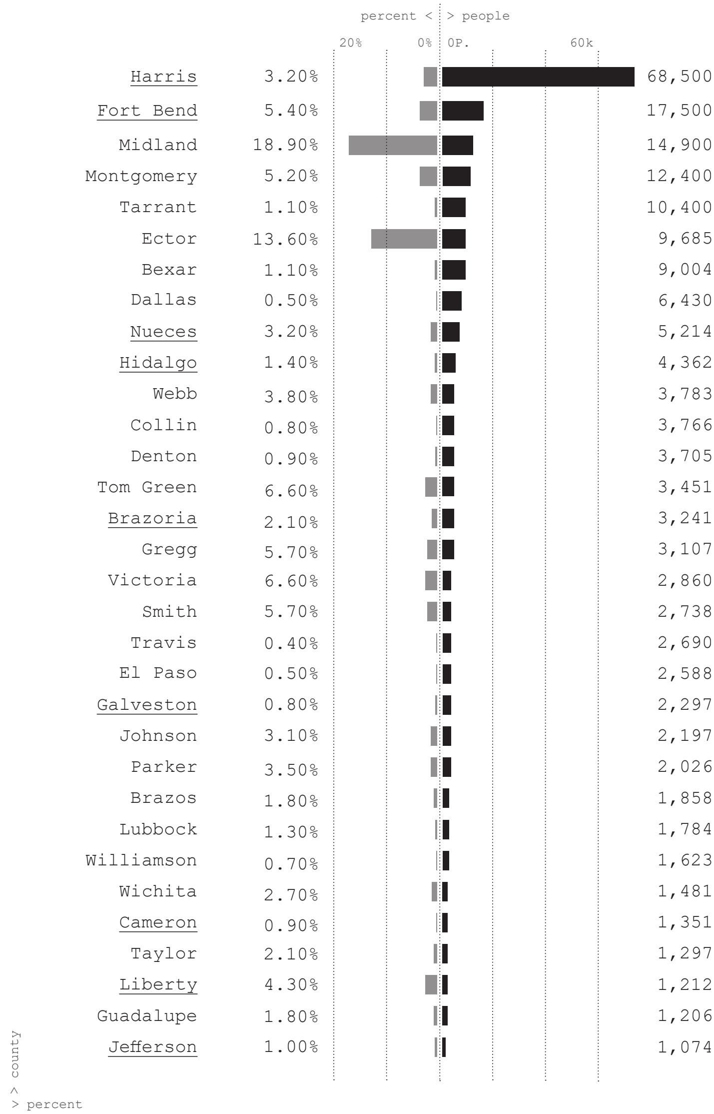


Figure 29. Pre-Covid percentage of population employed in the oil/gas/mining industry in the respective counties of Texas. Coastal counties are underlined. (Data source Statistics-Atlas, “Industries in Texas.”)

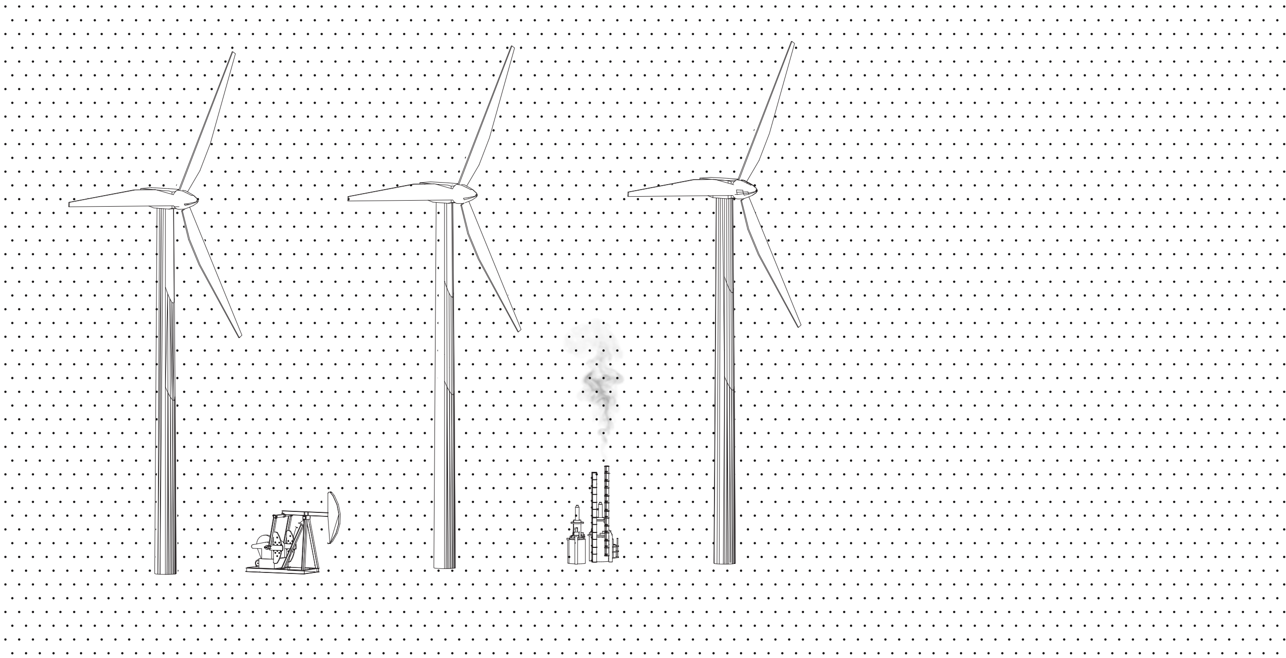


Figure 30. the State of Texas is the number one wind-producing state in the United States. While wind power is a more sustainable energy source, fossil fuels still perform strong.

than other states within the US. After forty-five years of limited oil export, the US has once again become the biggest producer of crude oil.[17] Among the 50 states, Texas has historically been a global player in the fossil fuel industry. If counted as a country, the State of Texas would rank as the third-largest oil producing country worldwide, after Russia and Saudi Arabia. While Texas is the biggest oil-producer in the US, it is also the biggest emitter of carbon dioxide. Relative to the US, the Texas economy employs +311 percent more people in the oil, gas, and mining industry than the average of all states combined.[18] This fact underlines how interwoven the Texas population and the petroleum sector are. The Texas Gulf Coast is of particular economic importance for the petrochemical industry, although most of the oil production of the state takes place in the Permian Basin, around Midland in West Texas. It is the marine infrastructure that allows the Ports of Houston to rank first, the Port of Corpus Christi to rank third, and the Port of Beaumont to rank eighth largest in the US by total tonnage in 2020.[19]

17 See EIA, "The 10 Largest Oil Producers and Share of Total World Oil Production in 2021."
18 See Statistics-Atlas, "Industries in Texas."
19 See BTS, "Tonnage of Top 50 U.S. Water Ports, Ranked by Total Tons."

The dependencies of the cities along the coast on the fossil fuel industry have historically been a major premise for developing (urban) infrastructure between Texas' eastern and southern borders to Louisiana and Mexico.[20] The resource-extraction economy started to boom in east Texas around 1900, after the opening of the Spindletop oil field and the Houston Ship Channel about a decade later.[21] Spindletop, a former salt dome near Beaumont, Texas, was one of the first major oil fields. Its symbolic nine-day gusher, supported the success of major corporations like Gulf Oil and Texaco. Dredging the Buffalo Bayou to allow for industrial activity, connected through the Houston Ship Channel to Galveston and the Gulf, was a major premise for the development of the thriving Port of Houston.[22] Similar engineering developments, dredging the Aransas Pass, enabled the Port of Corpus Christi to become a successful industry after its opening in 1926. With the dredging of human-made canals, the process of salt-water intrusion into the bays and estuaries had begun to change the coastal ecosystems and habitat for thousands of species, yet, it also enabled thriving economies and rapidly growing maritime logistics.[23]

During the rise of Fascism and the collapse of European democracies between the world wars, petroleum was about to replace the international gold standard and became the largest commodity in world trade.[24] Within the following decades, Texas' population changed from a predominantly rural population of 80 percent at the beginning of the century, to about 80 percent urban population in the 1980s.[25] In 2017, a total of 6,815,035 people lived in the counties along the Texas coast, including a population of 4,652,980 in Harris County around Houston, and 2,162,055 people distributed over the remaining 16 counties. These numbers highlight the fact, that the Texas coast is still 80 percent undeveloped. A little under a quarter of the Texan population lives along the coast while about 75 percent of the population lives within the

20 Cf. Feagin, "The Global Context of Metropolitan Growth: Houston and the Oil Industry." pp. 1204-1230.
21 Cf. Gillespie, "Rise of the Texas Oil Industry: Part 1: Exploration at Spindletop." pp. 22-24.
22 Cf. Misrach and Orff, Petrochemical America. pp. 119-126.
23 Cf. Turner et al., "The Impact and Mitigation of Man-Made Canals in Coastal Louisiana." pp. 497-504.
24 Mitchell, Carbon Democracy: Political Power in the Age of Oil. pp. 109-112.
25 Cf. Lessoff, Where Texas Meets the Sea: Corpus Christi and Its History. pp. 19-37.

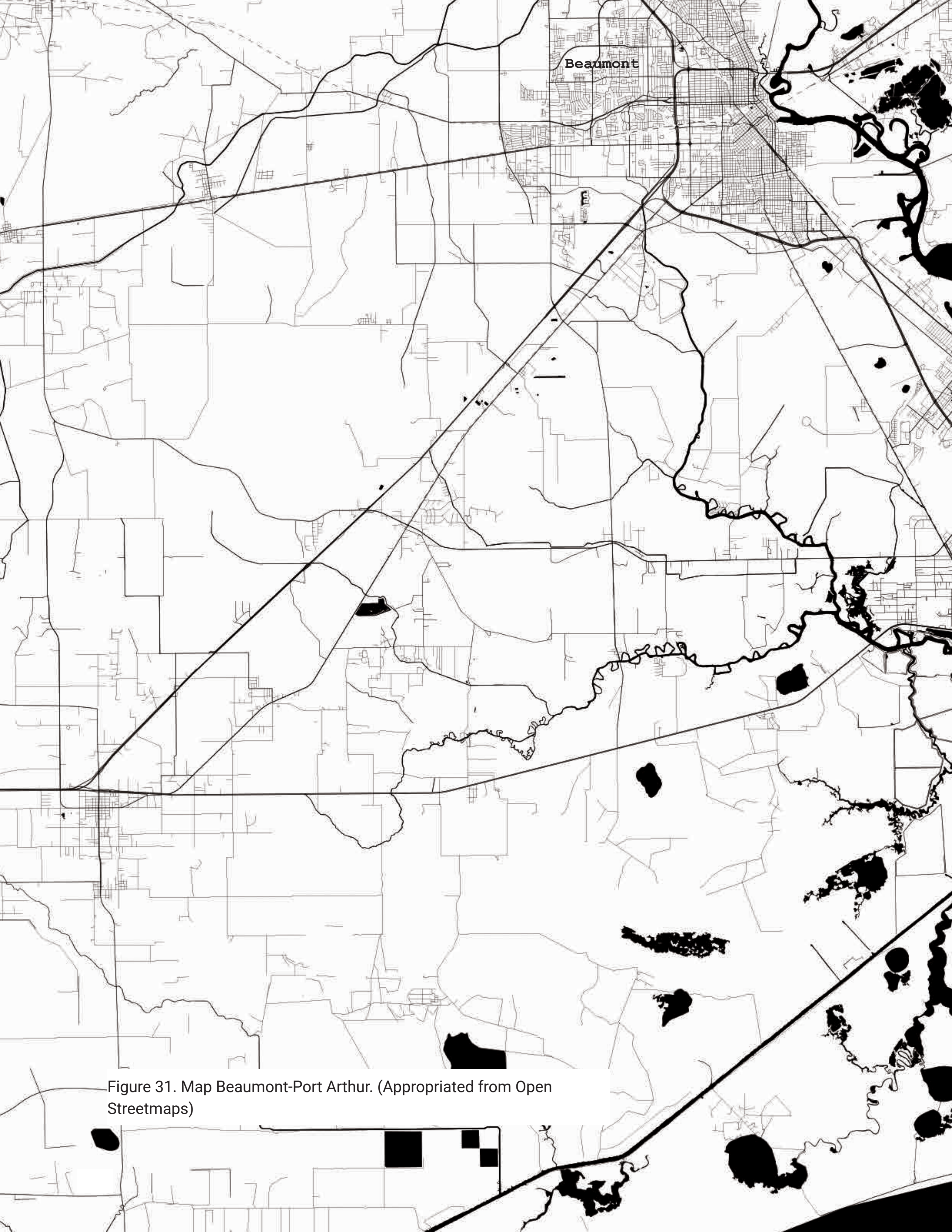


Figure 31. Map Beaumont-Port Arthur. (Appropriated from Open Streetmaps)


Orange
Nederland
Groves
Port Arthur
Sabine Lake
Sabine Pass
Gulf of Mexico

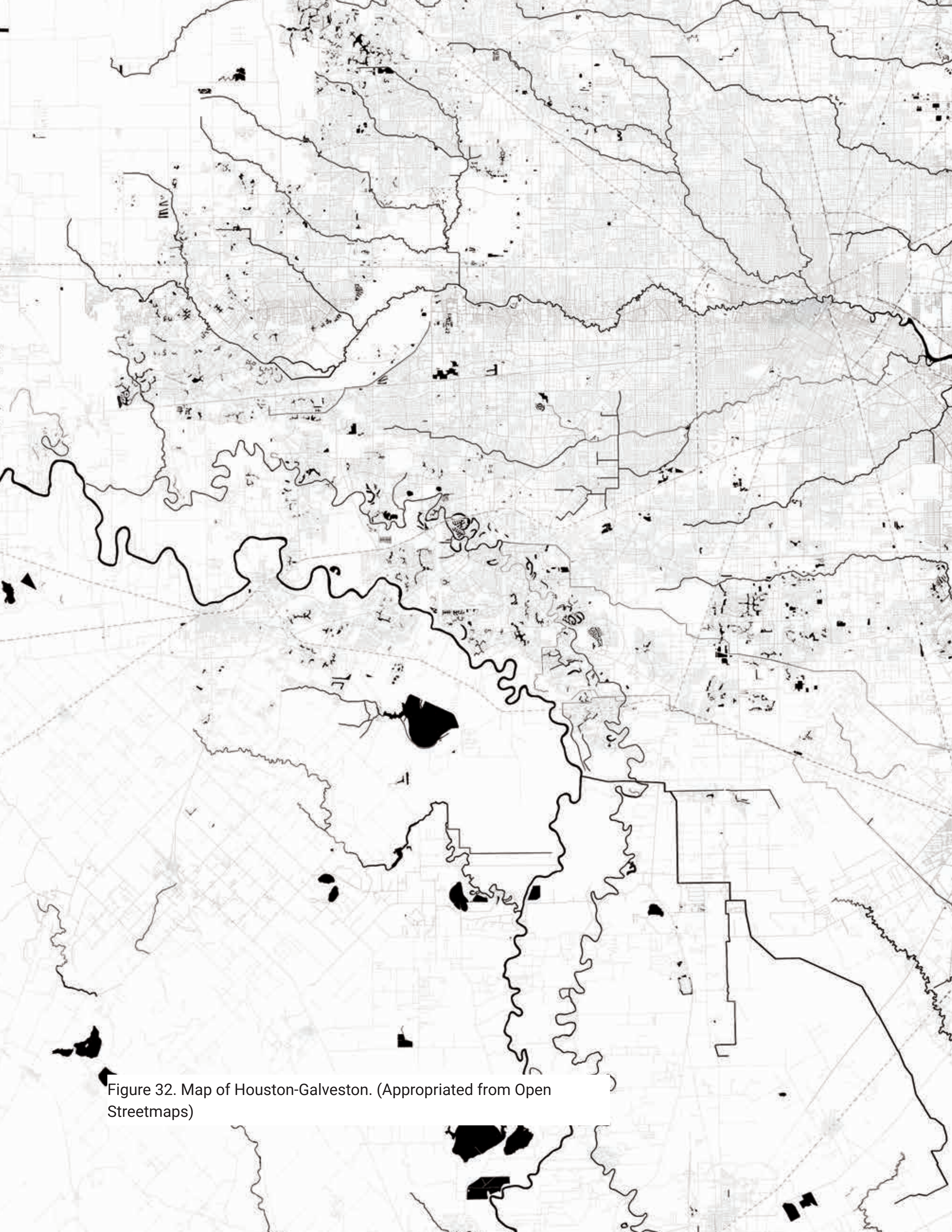


Figure 32. Map of Houston-Galveston. (Appropriated from Open Streetmaps)

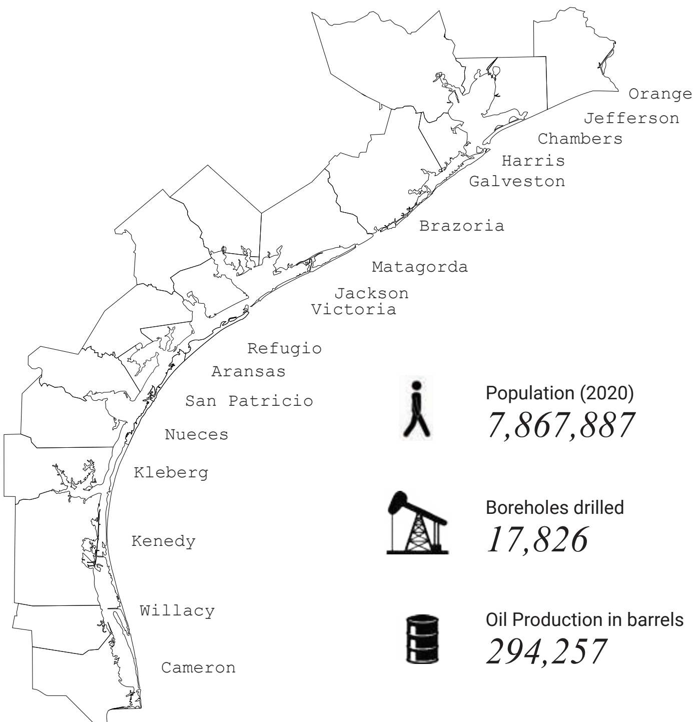

Baytown
Houston
Trinity Bay
Houston Ship Channel
League City
Galveston Bay
Texas City
Galveston
Gulf of Mexico

Figure 33. Map of the Corpus Christi Bay area. (Appropriated from Open Streetmaps)

Aransas Pass
ortland
Ingleside
La Quinta Ship Channel
Ingleside
on the Bay
Corpus Christi Ship Channel
Port Aransas
Corpus Christi Bay
Mustang Island
Gulf of Mexico
Laguna Madre
Padre Island

Population by Metro Area

406,505 Beaumont Area
6,482,592 Houston Area
36,719 Bay City Area
21,805 Port Lavaca Area
447,102 Corpus Christi Area
32,435 Kingsville Area
21,944 Raymondville Area
418,785 Brownsville Area



Population (2020)
7,867,887

Boreholes drilled
17,826

Oil Production in barrels
294,257

Gas Production in thousand cubic feet
1,202,181

Sea Ports
19

Figure 34. This diagram shows facts and figures on the daily operations of producing and refining oil and gas alongside with the total population in the coastal counties of Texas. (Data source: Statistics-Atlas.)

Texas triangle, which describes the area between Dallas, San Antonio, and Houston. While 25 percent of the Texas population lives in coastal counties, and 75 percent of the population lives within the Texas triangle, both of these numbers include Harris County as it is a coastal county and a part of the Texas triangle.[26]

Over the term of one century, Texas as a state of cotton and grain farmers, transitioned into the age of petrochemical industrialization, exporting oil and gas nationally and internationally. While the world started to connect the value of currencies to the movement of oil, Texas became a global petroleum super-power. All major urbanized zones along the Texas Coast share similar topographical characteristics, forming the basis establishing this type of cities. Located farther inland in a bay, all major cities along Texas' Gulf Coast have the advantage of being waterfront, yet not being fully exposed to coastal hazards like storm surge. Spanning from Sabine Lake to Upper and Lower Laguna Madre, the Bays of Galveston, Matagorda, San Antonio, Aransas, and Corpus Christi are home to the few larger cities along this mostly undeveloped coast.[27] Naturally protected by barrier islands, from Galveston Island in the north, to Padre Island in the south, cities along the Texas Coast share a resource and logistics landscape with the diverse members of the coastal ecosystem.[28] From preservation areas like the Padre Island National Seashore, across thousands of square-miles of undeveloped marshlands, the Texas Coast would have potential for many economic branches. The strategic geographic location was a factor in building and maintaining a variety of naval bases. Within the twentieth century, Houston and Corpus Christi have also established major university campuses including top-tier educational facilities. Especially the south Texas coast has also become a respectable tourist destination, offering quiet beaches along one of the world's longest sand bank islands.[29] The treasures of the Gulf Coast are diverse and precious, and an integral premise for establishing a specific type of coastal cities.

26 See Texas State Library, "Population, Texas Counties, 1990-2017."
27 Cf. Blackburn, A Texan Plan for the Texas Coast. pp. 54-73
28 See Spies, Senner, and Robbins, "An Overview of the Northern Gulf of Mexico Ecosystem."
29 See Weymer, Houser, and Giardino, "Poststorm Evolution of Beach-Dune Morphology: Padre Island National Seashore, Texas."

The Texas landscape is a fertile resource wonderland. The morphology of the coastal landscape around the four urban fields links the benefits of the coastal environment to the assets of the freshwater-suppling rivers that feed the bay areas. The water provided by rivers, bayous, creeks, and streams, supplies the coastal ecosystems along estuaries. The freshwater is enriched with carbon, nitrogen, and phosphorus, creating a habitat for microscopic plants and animals, which form the basis of the coastal food chain.[30] Wetlands, oyster reefs, and sea grasses are home to unique species.[31] Fisheries have historically been a major natural and economic asset way before the first boreholes punctured the sea floor of the Gulf. Harvesting the Texas land and water has provided economic wealth before and, hopefully, after oil.

Texas is the biggest oil-producer[32] and the biggest emitter of carbon dioxide in the United States[33] but it is also the number one producer of wind energy.[34] In 2020, roughly 20 percent of electricity in Texas was produced by wind turbines, as compared to 48 percent produced by natural gas and about 18 percent by coal.[35] The flat, coastal landscape is an ideal laboratory for wind farms, producing carbon-free energy (not taking the construction process of the turbines itself into account). Besides wind farms in North and West Texas, coastal wind turbines significantly contribute to Texas' wind energy. The transformation of energy sources towards sustainability has been ongoing and steadily increasing. In some parts of the state, the landscapes of oil and extraction have started to extract another (re)source: data. In 2017, Amazon CEO Jeff Bezos announced the opening of a 253-megawatt Amazon Wind Farm in Scurry County, in West Texas. This agglomeration of 100 wind turbines produces energy for 90,000 single-family houses, theoretically. Amazon is, alongside Google, Facebook, and Microsoft, one of many companies that invest in wind farms, powering gigantic data centers around the world. Texas has also become an attractive state for Tesla, SpaceX, and Facebook,

30 Cf. Blackburn, A Texan Plan for the Texas Coast. pp. 18-21
31 See Blomberg et al., "Habitat Assessment of a Restored Oyster Reef in South Texas."
32 See BTS, "Tonnage of Top 50 U.S. Water Ports, Ranked by Total Tons."
33 See EIA, "Energy-Related CO2 Emission Data Tables."
34 See WindExchange, "Wind Energy in Texas."
35 Ibid.

which completed the construction of a one-billion-dollar data center in Fort Worth, also powered by wind.[36] Wind power shifts the dependencies from oil slightly towards a renewable future, by adding variety to the energy industry. Yet, the Texas coast has also been a rich reservoir for lignite coal deposits from north-central Texas to the Rio Grande Valley at the border. Texas is the seventh largest producer of coal in the US, but the largest producer of lignite coal.[37] Along the Colorado River, the South Texas Nuclear Power Plant generates energy to supply Houston, Austin, and San Antonio. Located in the Matagorda Bay area, it is one of two nuclear plants in Texas. While wind, nuclear, and solar energy production have been growing over the past years, no energy sector is bigger in Texas as fossil fuels including oil, gas, and coal.

The significant geopolitical role of the Texas Coast may easily be put into perspective by looking at the activity of the major seaports and airports. In addition, the thousands of miles of railroad tracks, alongside the inter-coastal waterways, are connecting the Texas Coast nationally and internationally, by land, sea, and air. Oil is constantly moving through Texas and beyond into the nation, and the world. The infrastructure of the 19 Texas Gulf ports handled 598+ million tons of cargo and generated 5.4 million jobs related to the economic activity in 2019, according to the Texas Ports Association.[38]

Maritime logistics have shaped the natural and built environment for thousands of years. The Roman Empire expanded along its commercial roads, creating logistics landscapes within a network of trade. As logistics changed significantly within the process of industrialization, a global trade network started to enable urban growth at a rapid paste. In the US, the Interstate and Civil Defense Highway system and the standardized shipping container are examples of how streamlined transportation processes on both the scale of infrastructural projects and architectural objects, contributed to the physical making of urban environments. The concept of having a uniform container, easily adaptable to be transported on a track, train, or by ship, was a milestone in making global logistical processes possible. Cranes lifting these

36 Cf. Young, Machine Landscapes: Architectures of the Post Anthropocene.
37 See EIA, "Texas. State Profile and Energy Estimates."
38 See TxDOT, "Texas Ports."

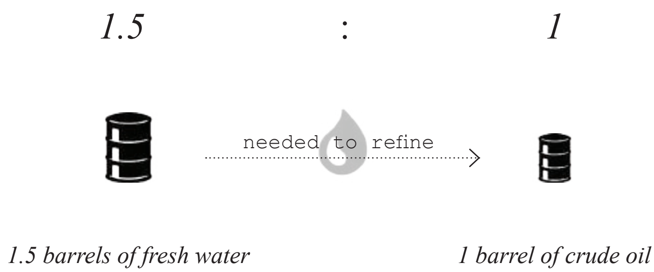


Figure 35. Fresh water demand for refining processes. (Data source: Weaver et al., "Potential Vulnerability of US Petroleum Refineries to Increasing Water Temperature and/or Reduced Water Availability.")

standardized vessels from one mode of transportation to another allowed for more efficiency in both time and manual labor.[39] It became increasingly inexpensive to ship items from warehouses to ports and then around the world. This masterpiece of industrial design opened global markets to consumers, offering affordable goods transported on public roads, waters, and in the air. As the global logistics landscape started to (inter)connect cities, the typology of port cities became even more crucial to feed the world with resources and products. While the global shipping industry flourished, the US interstate system grew to allow for point-to-point delivery to remote areas and to connect the major seaports on the East and West Coast. Alongside the expanding transportation network, large storage facilities, warehouses, cranes, and security measures became necessary, enhancing the elements of the port-city typology. The increasing importance of shipping created the demand for designating more sea- and airports to foreign trade zones: "*a foreign trade zone (FTZ) is an area designated by the federal government as outside of US Customs territory.*"[40] Besides several inland FTZs around industrial airports, the ports of Houston, Galveston, Corpus Christi, Free Port, and Port Arthur

39 Cf. Waldheim, "Landscape as Urbanism." pp. 69-72
40 See ITA, "U.S. Foreign-Trade Zones."

are declared foreign trade zones.[41] The success of many Texas ports is connected to the enormous amount of available land, making expansions in the transition period from traditional city harbors to FTZs, possible.[42] As in many global ports, land needs to accommodate shipping, staging, and delivery of goods. However, some Texas ports mainly focus on liquid bulk, in particular petrochemicals. Refineries and fields of oil tanks occupy Texas' coastal wetlands surrounding the respective ports. The global supply chain for crude oil and natural gas relies on Texas. Waldheim describes *"logistics landscapes,"* in the realm of Post-Fordist Economies, as highly engineered and optimized spaces for accumulating and distributing goods.[43] This might not represent the Texan reality of Post-Industrialization. Though, the global economy is moving past production and towards services, Texan ports are growing in a traditional industrial way. The toxic brownfield has not become a remnant of a petrochemical past, it is very much the motor of growth in the neo-liberal resource landscape of Texas. As of January 2019, a total of 135 petroleum refineries are operated in the United States. From 2015 to 2019, four out of five newly constructed refineries were opened along the Texas Coast.[44] The oil industry is growing, and it is growing in one of America's petroleum heartlands: Texas. This late oil boom goes back to 2015, when the US Congress lifted the 40-year-long US oil-export embargo. Ever since, Texas' ports have seen significant growth in producing, refining, and transporting oil and gas products. In South Texas, the Port of Corpus Christi increased its exports from 148,000 barrels per day in 2016 to 1,687,679 barrels per day on monthly average in May 2022.[45] This growth showcases the growth trends along the Gulf Coast. These increasing petrochemical activities demand both the natural and built environment to react, as petrochemical logistics require a variety of large-scale infrastructural components to operate, from ship channels to docking stations and storage units. These (re)growing landscapes of oil transform the coastline and its cities. They highly depend on the coastal ecosystem,

41 See Texas Governor's Office, "Texas Foreign Trade Zones."
42 Cf. Waldheim, "Landscape as Urbanism." pp. 69-85
43 Ibid. pp. 69-80
44 See EIA, "When Was the Last Refinery Built in the United States?"
45 See POCC, "Outbound Crude Oil – Domestic and Export Markets."

the access to the Gulf, and the freshwater provided by the rivers feeding the respective bay systems. On average, one barrel of crude oil requires about 1.5 barrels of fresh water to be refined.[46] The main water sources are surface and ground waters, with a majority of approximately 60 percent of the industrial water demand being supplied by municipal freshwater systems.[47] Texas' coastal territories require both, land and water to flourish. And while fresh water has become an increasingly valuable yet decreasing commodity, a growing petrochemical industry means a higher percentage of industrial water use, challenging the fragile urban ecosystems along the coast

3.b.
SURVIVING IN THE DANGER ZONE: THE CITES OF RESOURCE WONDERLAND

The face of the Texas Coast could not be more contrary: on the one hand, undeveloped, seemingly untouched landscape, a natural habitat for thousands of species. On the other hand, a symbol of the industrial age: a territory, where clusters of petrochemical facilities have changed the morphology of place. What might look like a skyline of a city from afar, are gigantic steel structures, perfectly engineered machines at the size of a small city.
Permanently inaccessible to the public, surrounded by tall fences, and ob-

46 See Weaver et al., “Potential Vulnerability of US Petroleum Refineries to Increasing Water Temperature and/or Reduced Water Availability.”

47 Ibid.

served by hight-tech equipment, these industrial objects operate 24/7, supplying the world with refined products, from gasoline to diesel and jet-fuel. The cities around and between the four Texan oil areas Beaumont, Houston, Corpus Christi, and Brownsville are *"the products of hydrocarbon capitalism: a culture of automobility predicated on the availability of cheap gasoline to fuel the particular form of the internal combustion engine known as the car."*[48] These urban agglomerations are a product of the process of suburbanization mixed with and accelerated by fossil fuels. The shape of Texas' cities is a consequence of burning this finite resource to commute, cool, heat, and to wrap goods. A concept, exported to the global market, ready to keep the world carbon-dependent.

The landscapes of oil are toxic. Besides the thousands of boreholes puncturing the earth's surface, refineries pollute air, soil, and water using a mix of chemicals to process crude oil, gas, and coal.[49] Refineries are major environmental polluters. Particulate matter, nitrogen oxides (NO_x), carbon monoxide (CO), hydrogen sulfide (H_2S), and sulfur dioxide (SO_2) are hazardous and toxic air pollutants.[50] Many of these pollutants are known or suspected cancer-causing agents. Refineries are also major contributors to ground and surface water contamination.[51] The use of deep-injection wells to dispose of waste water underground, is potentially contaminating drinking water. Soil contamination may occur during spills and other accidents in petroleum plants. Material collected and disposed in landfills may cause additional soil contamination off-site. Further, air and soil contamination may occur during the process of transporting crude oil before the refining processes, or while delivering the end product afterwards.[52] In the discourse of (landscape) architecture, brownfield contamination is important, as land ties the natural and built environment together.

48 Cf. Mostafavi and Doherty, Ecological Urbanism. pp. 450-455.

49 See Radelyuk et al., "Oil Refinery and Water Pollution in the Context of Sustainable Development: Developing and Developed Countries."

50 See Wake, "Oil Refineries: A Review of Their Ecological Impacts on the Aquatic Environment." pp. 131-140.

51 See Hazardous Substance Research Center, "Environmental Update #12."

52 Ibid.

Approaching architecture through an ecological lens, demands holistic thinking. If industrial or former industrial sites contaminate the water supply or pollute the air within, or at the edge of a city, town, or settlement, this contamination is part of a spatial regime.

Spatial because these contaminations unleash a sequence of repercussions in water supply and food chains. These impacts directly cause the natural and built environment and its inhabitants to suffer consequences from health risks to property damage. Waste water runoff into the Texas creeks, bayous, and rivers disturb the ecosystem. Fish and shrimps who live in, or farm animals who drink, water full of toxic byproducts of the petrochemical process, ultimately feed these toxins into the food chain.

Between the oil platforms and crude carriers off shore, tons of trash swims in the world's oceans. Plastics, in particular, leave permanent negative impacts on the marine environment. Tracking the beaches of the five states on the US Gulf shores, on nine barrier islands from North Padre Island, Texas to Santa Rosa, Florida, scientists found ten times the amount of trash being washed onto the Texas Coast than on the shores of any other state. Between 69-95 percent of this trash was plastics.[53] The components for plastic production are refined from crude oil. These oils are used as feedstock for petrochemical crackers that produce the basic building blocks for making plastics. Most of these materials are produced at crude oil and petroleum refineries, or are byproducts of natural gas processing.[54]

Plastic pollution in the marine environment of the Gulf of Mexico, pose chemical and physical threats to the ecosystem. Plastic particles can be found in coral reefs, beaches, rivers, estuaries, and even the deep sea.[55] The negative impact of microplastics on sea-life is evident, however, the interna-

53 See Wessel et al., "Accumulation and Distribution of Marine Debris on Barrier Islands across the Northern Gulf of Mexico."

54 See EIA, "How Much Oil Is Used to Make Plastic?"

55 See EPA, "Trash Free Waters."

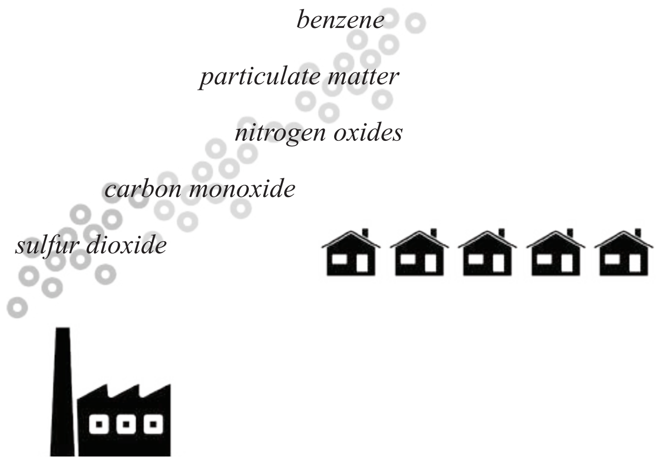


Figure 36. Common pollutants of refining processes, causing a health risk for humans. (Data source: Wake, "Oil Refineries: A Review of Their Ecological Impacts on the Aquatic Environment." pp. 131-140.)

tionally peer-reviewed expert panel reports by EFSA calculate, that *"microplastics may have a negligible effect on the exposure to some pollutants and additives considering the total dietary exposure of humans."*[56] The built environment is embedded into the natural environment. Permanently. The complex logistical systems which ship goods to remote areas and provide fuel for transportation, heating, cooling, and energy production, are harming the environment and everyone within that environment, severely. Though some consequences may do less damage than others, the long-term impacts on the food-chain cannot be fully investigated just yet.[57] Certainly, the impacts on fauna and flora have been devastating. Besides air, water, soil contamination and oil-based plastic in seafood, petrochemicals are also part of modern agricultural processing, especially in fertilizer production.[58] In many ways,

56 Barboza et al., "Marine Microplastic Debris: An Emerging Issue for Food Security, Food Safety and Human Health." p. 336
57 Ibid. pp. 336-343
58 See Misrach and Orff, Petrochemical America. p. 121

BEAUMONT - PORT ARTHUR

Figure 37. Beaumont - Port Arthur is the most northern petrochemical cluster along the Texas Coast located at the Louisiana border. About 15% of the 406,506 residents living in 151,403 households work in manufacturing jobs or the oil/gas/mining sector.(Data source: Statistic Atlas, US Census Bureau)

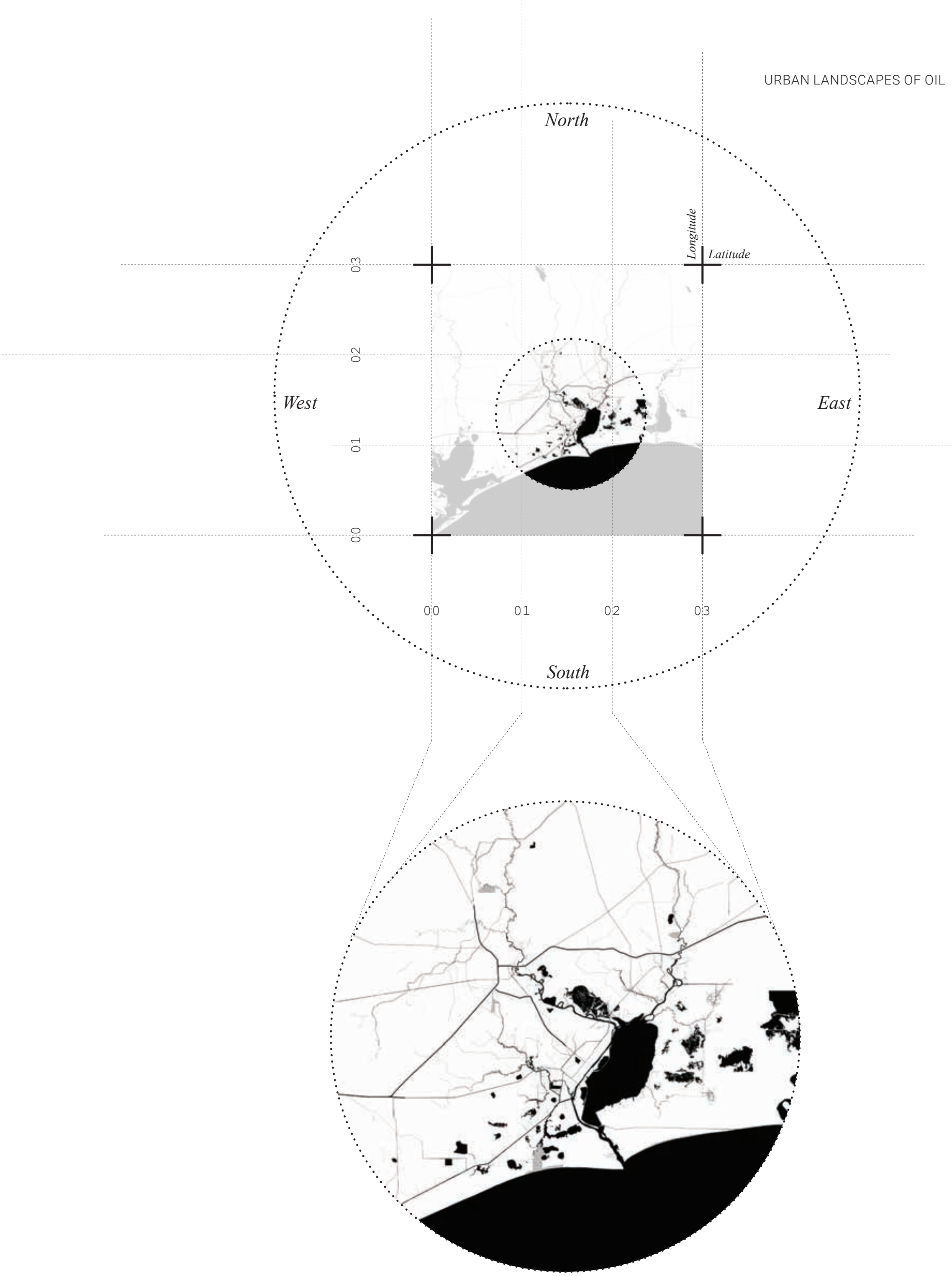
fossil fuels have become part of the water we drink, the food we eat, and the air we breathe. Alongside these pollutions, spills and accidents are a major threat to ecosystems on land and water.

The danger of petroleum facilities drilling for, or refining, crude oil on land, contaminating grounds, air, and water, is evident.[59] While the environmental impact of offshore drilling sites might be as severe, leaks and spills are often not detected right away, given their remote location outside of human settlements. Exposed to the extreme environment offshore, the thousands of oil platforms in the Gulf of Mexico have to withstand wind and waves. The steel structures within this humid and salty environment are aging, corroding, and not always able to handle the forces of nature anymore. In 2004, category three Hurricane Ivan damaged and sank the Taylor Energy Mississippi Canyon 20 drilling platform, 12 miles off the coast of Louisiana.[60] While the Taylor Energy Company estimated that three to five gallons per day had been leaking into the Gulf, the scientists from the National Centers for Coastal Ocean Science had calculated that up to 500 times this amount was released into the marine environment.[61] The research teams' calculations estimate between nine and 108 barrels (378 to 4,536 gallons) were spilling into the Gulf per

59 Cf. Eyayo, "Evaluation of Occupational Health Hazards among Oil Industry Workers: A Case Study of Refinery Workers."

60 See NOAA, "NCCOS Scientists Publish Flow Rates for 14-Year-Long Oil Spill in Gulf of Mexico."

61 Ibid.


North
Longitude
Latitude
West
East
0.3
0.2
0.1
0.0
0.0
0.1
0.2
0.3
South

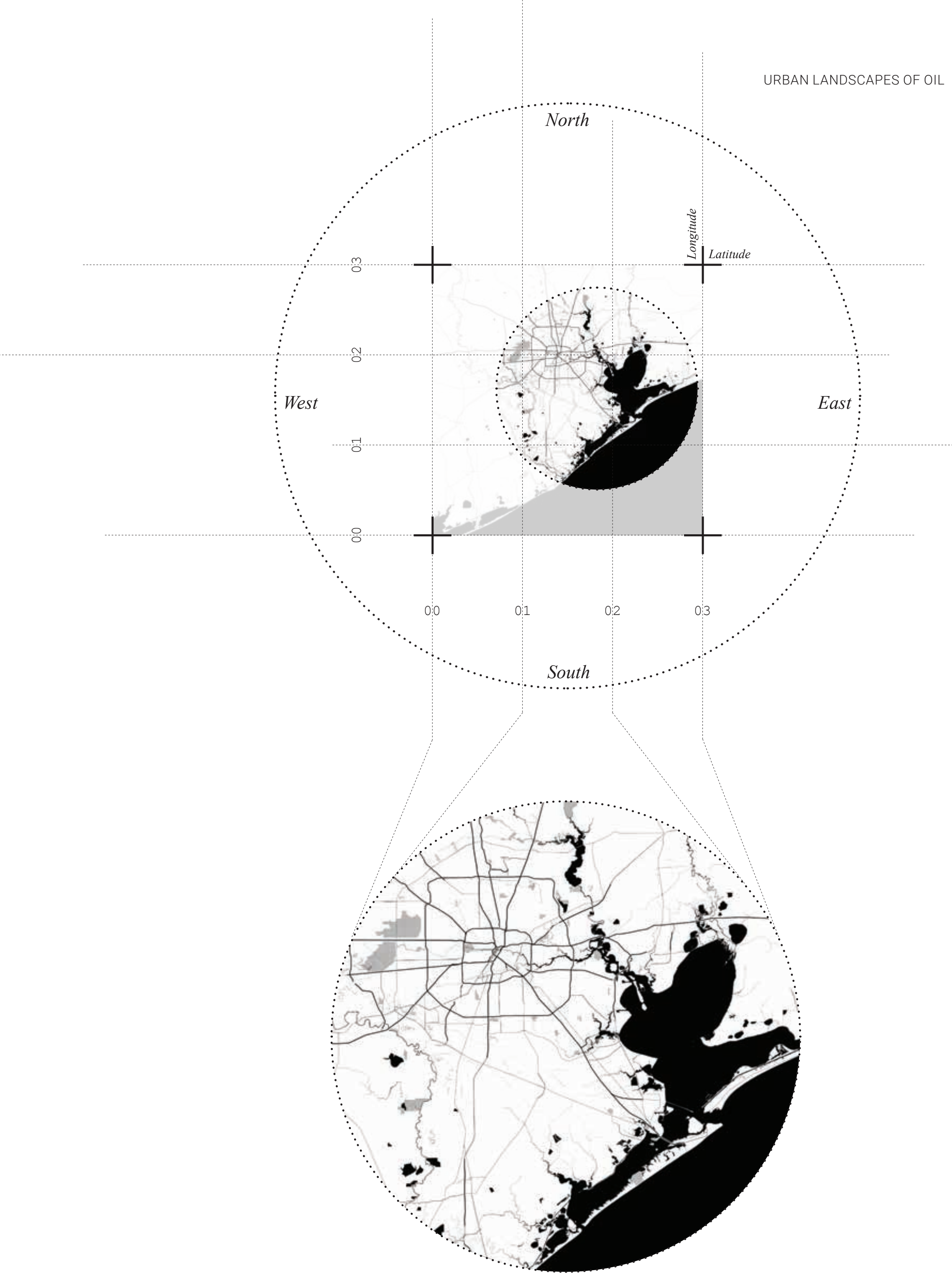
HOUSTON - GALVESTON

Figure 38. Houston - Galveston is the largest petrochemical cluster along the Texas Coast located just south of the Louisiana border. With 6,482,592 residents it also is the largest metro area along the entire Gulf Coast. Approximately 14% work in manufacturing jobs or the oil/gas/mining sector. (Data source: Statistic Atlas, US Census Bureau)

day.[62] The remnants of this platform have been leaking for over 14 years, making this oil spill the worst environmental offshore disaster in history. The extreme discrepancy between the estimated gallons spilling into the Gulf daily, provided by the operator, versus the actual figures provided by a collaboration of various research centers, over a time period of 14+ years, shows how silent spills may have poisoned the Gulf in the past beyond the known catastrophes.

Perhaps the most publicly known oil disaster in the Gulf is the Deepwater Horizon spill.[63] An explosion sank this oil rig operated by British Petroleum and killed eleven people on April 20, 2010. Underwater cameras showed, that oil and gas were leaking into the deep sea roughly 1,500 meters below the Gulf's sea level.[64] This permanently dark underwater environment off the coast of Louisiana, set extremely difficult conditions for the process of capping the boreholes. Over 87 days, an estimated 3.19 million barrels leaked into the Gulf, impacting 2,092 kilometers or 1,300 miles of shoreline in five states.[65] Marine life has been exposed to oil and gas by inhalation, aspiration, ingesting contaminated sediment, water, or prey, or by absorbing contaminants through their skin. Beyond these catastrophic events, their impact on human life, and the marine environment, the use of highly toxic dispersant added an-

62 Ibid.
63 See de Wolf, "Crisis Management: Lessons learned from Bp Deepwater Horizon Spill Oil."
64 Cf. Beyer et al., "Environmental Effects of the Deepwater Horizon Oil Spill: A Review."
65 Ibid.


North
South
West
East
Longitude
Latitude
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0.3
0.0
0.1
0.2
0.3

CORPUS CHRISTI BAY

Figure 39. The Corpus Christi Bay Area is the fastest growing petrochemical cluster along the Texas Coast located south of Houston. About 10% of the 447,102 residents living in the metro area work in manufacturing jobs or the oil/gas/mining sector. (Data source: Statistic Atlas, US Census Bureau)

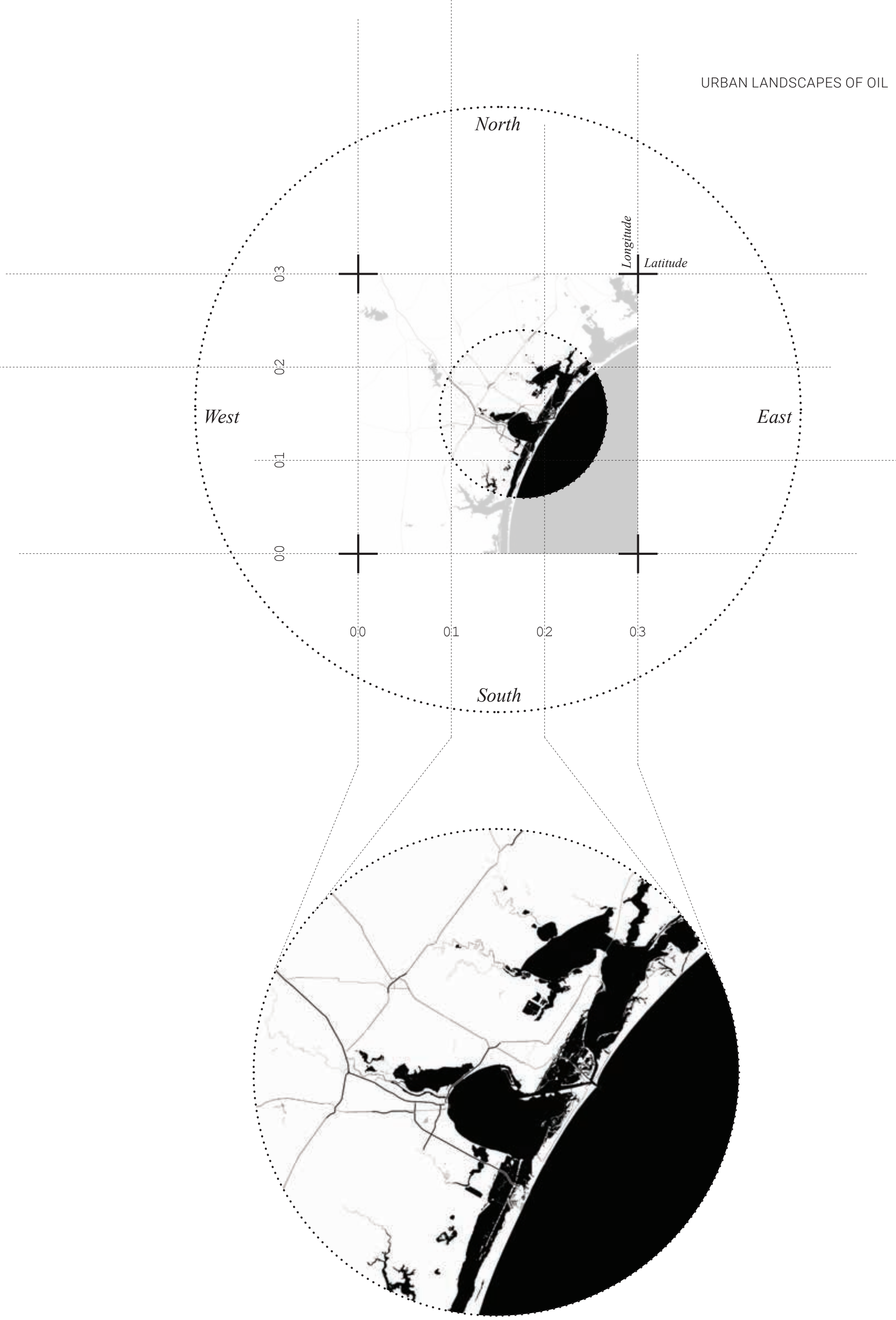
other layer of ecological hazard to this disaster.[66] Corexit 9500A and Corexit 9527A had been used as dispersant and were sprayed onto the Gulf's surface in the aftermath of the Deepwater Horizon spill.[67] Corexit contains dangerous toxins which may cause injury to red blood cells, kidney or the liver, according to the manufacturer's safety data sheet.[68] About one million gallons of dispersant were applied to the impacted water surface through airplanes, and an additional 771,000 gallons were directly pumped into the water. Besides the risks for humans, other species like fish, corals, sea turtles, and birds have been severely impacted by the use of these toxins. Though other countries prohibit the use of Corexit, the Environmental Protection Agency EPA allows the use of Corexit 9500 and 9527.[69] However, BP used a more toxic and less effective dispersant, produced by a manufacturer working in joint venture with the Exxon Chemical Company. While the EPA was aware of the use of unauthorized dispersant, they did not intervene in the first 30 days after the explosion, silently allowing these toxins to be spread. After the first month, EPA required BP to use a less toxic and more efficient dispersant. While BP

66 Cf. Brakstad, Lewis, and Beegle-Krause, "A Critical Review of Marine Snow in the Context of Oil Spills and Oil Spill Dispersant Treatment with Focus on the Deepwater Horizon Oil Spill."

67 Cf. Gray et al., "Presence of the Corexit Component Dioctyl Sodium Sulfosuccinate in Gulf of Mexico Waters after the 2010 Deepwater Horizon Oil Spill."

68 See Land et al., "Safety Data Sheet Corexit TM Ec9580a Safety Data Sheet Corexit TM Ec9580a."

69 Cf. Gray et al., "Presence of the Corexit Component Dioctyl Sodium Sulfosuccinate in Gulf of Mexico Waters after the 2010 Deepwater Horizon Oil Spill."


North
Longitude
Latitude
0.3
0.2
West
East
0.1
0.0
0.0
0.1
0.2
0.3
South

BROWNSVILLE

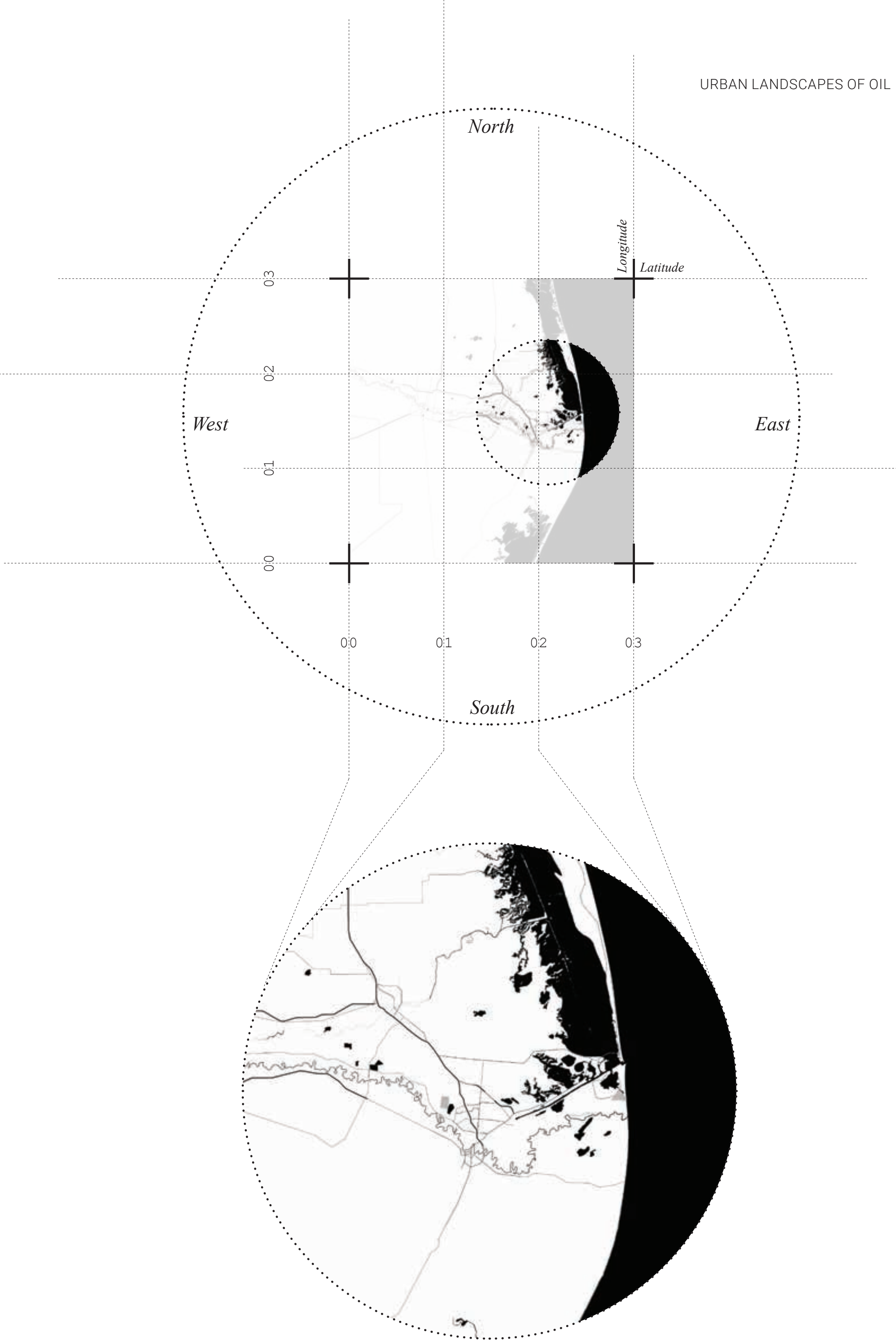
Figure 40. The Brownsville Area is the smallest petrochemical cluster along the Texas Coast located slightly north of the Mexican border. About 7% of the 418,785 residents work in manufacturing jobs or the oil/gas/mining sector. (Data source: Statistic Atlas, US Census Bureau)

kept using Corexit 9500A and Corexit 9527A, less dispersant was applied in response to the EPA's request.[70] This example of post-disaster management highlights the difficult relationship between governmental authorities and private corporations in the drilling industry. The list of spills on the world's oceans and lands is long and seems to get even longer, even faster.[71] Toxic chemicals used in various industrial processes may impact the environment. Water collects and distributes toxic materials. It transports fertilizers used in agricultural operations, all the way into the Gulf of Mexico and beyond. Besides these major ecological disasters in the Gulf, many smaller spilling accidents happen every year. The latest oil spill occurred in May 2019, in the Houston Ship Channel. It caused more than two million gallons of reformate, an oil-refining byproduct, to contaminate the water.[72] In the daily operations of petroleum processing, oil and gas get pumped into pipelines and trucks, to be stored in fields of oil tanks, to then get processed in treatment plants, to finally get shipped around the world. The landscapes of oil are marked by these logistical operations. Fauna and flora suffer the consequences often more so, than people inhabiting the built environment where this activity occurs.

70 Cf. Ecological impacts of the Deepwater Horizon oil spill: implications for immunotoxicity.

71 Cf. Yin, Hayworth, and Clement, "A Tale of Two Recent Spills—Comparison of 2014 Galveston Bay and 2010 Deepwater Horizon Oil Spill Residues."

72 See NOAA, "$15.3 M Settlement Proposed for Oil Spill Case in Galveston Bay, Texas."


North
Longitude
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0.3
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South

Figure 41. The Deepwater Horizon Oil Spill in the Gulf of Mexico in 2010 impacted large surface areas off the shores of Louisiana and Texas. Darker gray shows most impacted areas, lighter gray shows less impacted. The circles show offshore drilling sites. (Appropriated from Open Streetmaps)

Besides human-made disasters, the Texas Coast is, like most coastal areas, an environmental danger zone. Threats to the built environment also occur naturally, and many times unpredictably. Statistically, hurricanes occur every six years, measured in fifty-mile segments, along the Texas Coast.[73] Since 1829, the longest time period without a hurricane striking Texas, was a ten-year period, from 1989 to 1999, while in 1886, Texas was hit by four hurricanes in one year.[74] While extreme wind speeds may be life-threatening, they definitely cause severe damages to the built environment. Even more dangerous than wind, are the heavy rainfalls tropical storms, cyclones, and hurricanes bring, flooding cities and lands. Making landfall as a category four storm on August 25, 2017 in Rockport, Texas, Hurricane Harvey brought devastating impacts. After meandering above Victoria, Harvey moved farther north, bringing 50+ inches of rainfall to Houston.[75] Harvey was the sixth major storm hitting Texas in the new millennium, yet has also been the most deadly storm in Texas history taking 108 lives, followed by Hurricane Ike in 2008 (84 deaths), and Rita in 2005 (59 deaths).[76] Harvey damaged approximately 345,000 housing units in the Houston area, yet one of the most devastating impacts on both the natural and built environment, was done by hazardous spills and toxic releases as storm-water flooded the petrochemical sites around Galveston and Trinity Bay.[77] Explosions and fires released toxic pollutants into the air leading to severe health problems in the days after Harvey.[78] NASA, local to the Houston area, prepared airplanes with high-tech equipment to monitor the toxic air pollutants, aiming to warn residents about potential health risks. Texas authorities and the EPA "stopped the NASA scientists from doing so, arguing that the air pollution data collection would cause "confusion" and might "overlap" with their own analysis."[79] This is another example of conflicts between private and collective interests.

73 See NOAA, "Hurricanes in History."
74 Ibid.
75 See Blake and Zelinsky, "National Hurricane Center Tropical Cyclone Report: Hurricane Harvey."
76 See Roth, "Texas Hurricane History."
77 See Qin, Khakzad, and Zhu, "An Overview of the Impact of Hurricane Harvey on Chemical and Process Facilities in Texas."
78 See AIA, "Harvey and the Aftermath."
79 Cf. UCSUSA, "EPA Blocks NASA from Monitoring Air Pollution Levels in Houston After Hurricane Harvey."

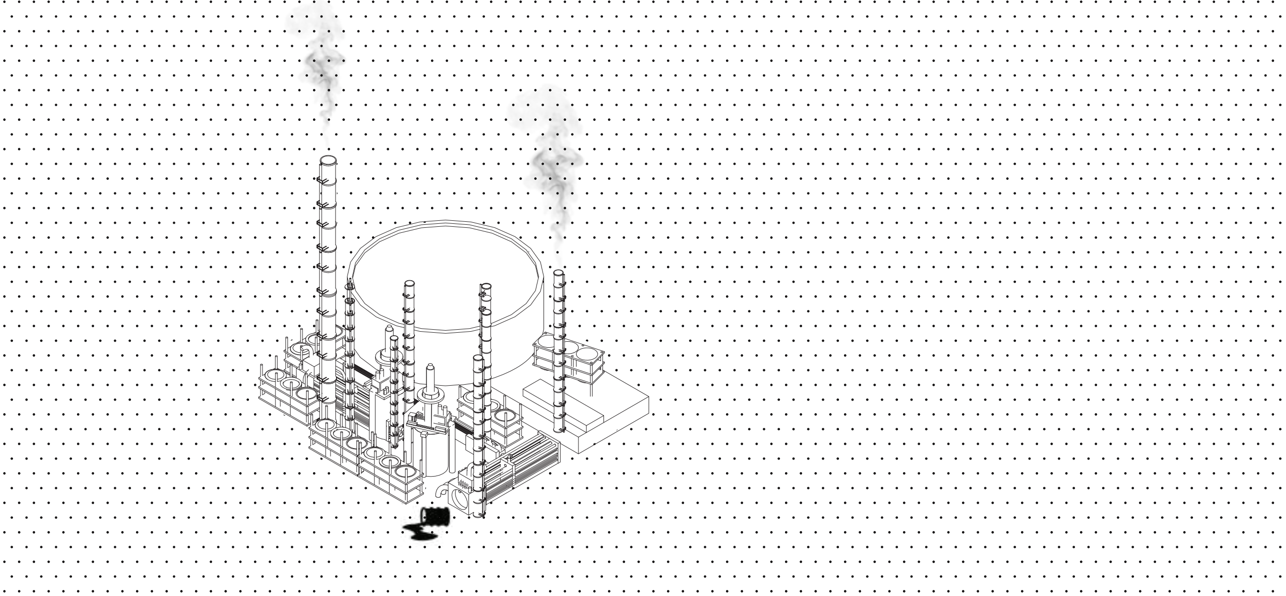


Figure 42. Oil refineries are industrial typologies that pollute air, soil, and water as they process petrochemicals for a variety of uses in every-day life.

> *"Some 500 chemical plants, 10 refineries and more than 6,670 miles of intertwined oil, gas and chemical pipelines line the nation's largest energy corridor. Nearly half a billion gallons of industrial wastewater mixed with storm water surged out of just one chemical plant in Baytown, east of Houston on the upper shores of Galveston Bay. Benzene, vinyl chloride, butadiene and other known human carcinogens were among the dozens of tons of industrial toxic substances released into surrounding neighborhoods and waterways following Harvey's torrential rains."*[80]
>
> *> SIERRA CLUB, 2018*

(Petro)chemical industries pose enormous ecological risks, especially during natural disasters like hurricanes, tropical storms, and the flooding, as the toxic materials spill into the natural and built environment.

80 Sierra Club, "Toxic Aftermath of Hurricane Harvey Covered Up In Texas."

The post-disaster recovery began quickly after Hurricane Harvey. Thousands of volunteers working with the red cross offered immediate help providing medical assistance, food, water, and shelter. In fact, though, day one after a hurricane is only an undefined number of days away from the next disastrous storm and unpredictable floods. While the reconstruction of private and public infrastructure began, the measures to protect the built environment with coastal engineering projects of an unseen scale are underway, too. The Ike Dyke, a series of dykes, levees, and flood gates, aim to mitigate some flood-related impacts and adapt to rising sea-level and more intense storms.[81] However, it is crucial to not just treat the symptoms but also the causes of these disasters threatening the urban ecosystem with ever-increasing frequency and scale.

3.c.
BUILDING A NEW TYPE OF SETTLEMENT: THE COASTAL OIL CITY

The cities in the coastal danger zone have always been built on unstable grounds. The forces of nature belong to life in coastal cities. Finding the shared characteristics that establish the coastal city as an urban typology goes hand in hand with an inventory analysis of the city's elements. Large-scale infrastructural projects have been built around the world to protect vulnerable yet strategically located coastal towns for millennia. Looking at the protective infrastructural elements of coastal cities starts with nature. The planet has developed smart and highly adaptable mechanisms at the soft edges between water and land.

81 Cf. Tolentino-Serrano, "In the Eye of the Storm: Houston after Hurricane Harvey."

Figure 43. Birds-eye view of sand-dunes in North Padre Island off the coast of Corpus Christi.

Figure 44. Street-view of Nueces Street in Corpus Christi looking towards a Citgo Refinery.

Figure 45. Birds-eye view of Refinery Row located in the inner harbor of Port Corpus Christi.

Natural beaches have been exposed to the forces of nature since the formation of land. They have always been able to adapt to changing (natural) conditions. Huge storms might change the size or location of a beach but they will ultimately regenerate themselves naturally. Coastal engineers aiming to protect the built environment along the shorelines of the world, created huge problems for local ecosystems, often preventing natural regeneration processes after storms. Flexibility is crucial for the survival of a beach. Going back to 3500 BC, and perhaps even before that, mankind practiced coastal engineering on the shores of the Mediterranean Sea, the Red Sea, and the Persian Gulf.[82] In the history of world trade across the oceans, navigation channels and harbors, as well as impressive pre-industrial constructions of wave shelters, have been added to the coastal landscapes. The knowledge gathered in early civilizations from the Phoenicians, Greeks, Egyptians, and Romans was based on sophisticated construction methods, using cement to harden underwater structures. Even the dredging of ports and channels allowed for areas in the hinterlands, or upstream a river, to become accessible to Roman fleets.[83]

The concept of coastal areas as tourist destinations also has its origins way before the French Revolution. Pompeii, Italy, for instance, served as a holiday location during volcanic eruptions of the Vesuvius going back to 30 BC. Along the shore of New Jersey, the development of a tourist-oriented industry already started in the early 19th century, at a time, when the Texas coast had barely been settled. To ensure the protection of waterfront developments, either soft or hard stabilization concepts are applied to keep shorelines in place. Soft stabilization or beach replenishment utilizes natural materials from other areas, often close to the existing beach: sand may be transferred from another beach or from lower or upper beach areas. Hard stabilization involves the construction of gray infrastructure, built objects permanently put into the coastal landscape, such as a seawall, groin, or offshore breakwater. These engineered constructions aim to prevent beach erosion, and/or trap and accumulate sand to ensure the stability of a beach.[84]

82 Cf. Kraus, "History and Heritage of Coastal Engineering."
83 Cf. Pilkey and Cooper, The Last Beach. pp. 40-43
84 Ibid. pp. 43-46

Hard infrastructure is often associated with negative impacts on marine ecologies.[85] These impacts include the erosion of adjacent beaches, increasing the height of surf-zone waves, reduction of water quality, turtle and bird nesting, or even the loss of well-functioning ecosystems.[86] Seawalls, groins, jetties, and other hard infrastructural typologies have been constructed along the Gulf of Mexico and the Texas coast ever since the 19th century. On September 8, 1900, a major category four storm on the Saffir-Simpson Hurricane Wind Scale hit the low-lying barrier island Galveston, located two miles off the shore of Texas City in the Houston area. At the time, Galveston was a Texan boom-town with a thriving economy and tourism, counting 40,000 inhabitants.[87] The storm surge of approximately 15 feet damaged 3,500+ buildings and took well over 6,000 lives.[88] A board of engineers proposed the construction of a curved-faced concrete seawall rising 17 feet above mean low tide and stretching over 3 miles along the shore of Galveston Island. Behind the seawall, a 100-foot wide embankment was built alongside the gigantic undertaking of extensive grade raising throughout the city. Completed in 1911, the elevation of major parts of the city was raised by 17 feet: a height-difference so extreme, that ground floors were transformed into basements while second floors became the new ground-floors.[89] The 1900 storm of Galveston permanently influenced the development of the cities along the Texas Coast. This severe storm brought attention to the risk of human settlements along the shore of Texas. With the dredging and deepening of the Houston Ship Channel in 1909 and its opening in 1914, Houston was able to benefit from its geographical location farther inland and slightly more protected from major storms. Houston replaced Galveston as fastest growing port city of Texas.[90] Similar developments took place in the other major port areas of Texas and beyond. The Gulf Intercoastal Waterway, a man-made canal, was constructed over decades and now connects ports over 1,300 miles along the Gulf shore

85 See Sayers, Walsh, and Dawson, “Climate Impacts on Flood and Coastal Erosion Infrastructure.”
86 Ibid.
87 Cf. Green, Story of the 1900 Galveston Hurricane. pp.1-4
88 Ibid. pp. 4-7
89 Cf. Pilkey and Cooper, The Last Beach. pp. 53-55
90 See ASCE, “Houston Ship Channel.”

from Brownsville, Texas to St. Marks, Florida.[91] The Texas part of the Intercoastal Waterway spans 423 miles, handles over 50 percent of the United States' water traffic, and more than 90 million tons of cargo per year.[92] As part of the Gulf Intercoastal Waterway, the Sabine–Neches Waterway connects Port Arthur and Beaumont to the Gulf since 1912.[93] Completed in 1936, the Brazos Island Channel and Port Isabel Channel were dredged to connect the Port of Brownsville and the Rio Grande Valley to the Gulf of Mexico.[94]

Ship channels, providing access from bays to the oceans, are crucial elements of a coastal city. Especially in port cities, as the sea bound logistical connection to the world often forms the backbone of the maritime economy. One of the oldest ship channels in Texas is Aransas Pass, a gateway that links the Intercoastal Waterway and the Gulf of Mexico in the Corpus Christi Bay area.[95] Located between Mustang Island and St. Joseph Island, this channel goes back to 1528 and has been deepened gradually over centuries. In the mid-18th century, Texas legislature had authorized to dredge a seven-mile long deepwater entrance at Aransas Pass. Over years, efforts to stop the erosion of the channel failed. Dikes, revetments, sand fences, jetties, brush and stone mattresses, and tree plantings could not deliver the expected outcome of a permanently stabilized channel. It was not until 1885 until two jetties, a breakwater, and a mattress revetment finally allowed for permanent deepwater access through Aransas Pass.[96] Following a hurricane in 1919, the 3,600 meter or 12,000-foot-long seawall of Corpus Christi was built alongside the downtown marina. Opened in 1923, the deep-water Port of Corpus Christi was connected to the Gulf by extending the Aransas Pass ship channel, through Laguna Madre and Corpus Christi Bay. Over the past decades, the hurricane defense systems and flood protection systems along the Gulf shore have been maintained and expanded. These gigantic concrete monuments of the Anthropocene, aiming to keep the shores in place, have fulfilled their engi-

91 Cf. Alperin, History of the Gulf Intracoastal Waterway. pp. 2-4
92 Ibid. pp. 4-7
93 Cf. TxDOT, "Gulf Intracoastal Waterway."
94 See Port of Brownsville, "History."
95 Cf. Lessoff, Where Texas Meets the Sea: Corpus Christi and Its History. pp. 43-44
96 Cf. TSHA, "Aransas Pass."

neering task to a certain extent. However, unpredictable storms and even more so, extreme flooding, show the limits of coastal engineering in the age of global warming. Disastrous storms like Hurricane Harvey, Irma or Maria,[97] all happening in 2017, are examples of high-intensity storms, charged by global warming, due to the increased temperature of the Atlantic Ocean.[98] In the aftermath of Hurricane Katrina in 2005, 14 billion Dollars have been spent to build a 2.5 kilometer or 1.8-mile-long seawall across Lake Borgne, off the shore of New Orleans, to protect the city from storm surges as high as 8 meters or 26 feet.[99] An even bigger investment is the “Ike Dike” proposal off the shore of Galveston. The proposal includes a 112-kilometer or 70-mile-long system of levees and sea gates to protect the Houston-Galveston area for estimated costs of 36 Billion Dollars.[100] Enormous infrastructural projects have been, and will be necessary to protect coastal cities from natural disasters.

The petrochemical industry along the Texas Coast is a major source of carbon emissions, of contaminating and polluting air, soil, and water.[101] Yet, these facilities, located in Foreign Trade Zones are usually fenced, high-security entities, not accessible to the public. A view of a refinery or the fields of oil tanks often is only possible from afar. The closest look into a refinery is usually provided when driving over a bridge.

> *Suddenly, the city and its civil infrastructure, disappear in the rear mirror, and while the horizon appears ahead, stretching through the wide and open lands of Texas, one might get a glimpse into the world of industrial petroleum engineering along rivers, bays, and ship channels.*

97 See Roth, “Texas Hurricane History.”
98 See Elsberry and Garwood Jr, “Sea-Surface Temperature Anomaly Generation in Relation to Atmospheric Storms.”
99 See Luettich, “Reducing Coastal Risk–Structural Protection Around Greater New Orleans.”
100 See Texas A&M University, “Response to USACE Texas Coastal Study.”
101 See Takht Ravanchi and Sahebdelfar, “Carbon Dioxide Capture and Utilization in Petrochemical Industry: Potentials and Challenges.”

Due to the increased oil production and export of crude oil and natural gas, Texas' ports are growing. These growth processes demand infrastructural adaptations. While more land is sealed, covered with concrete, and while more toxic byproducts are being pumped into the earth, the reality of contemporary deep-sea ports is to provide access to bigger barges and ships carrying more barrels around the globe. The new era of VLCCs, Very Large Crude Carriers, and ULCCs, Ultra Large Crude Carriers, are a challenge for the natural and built environment. Bridges as an infrastructural typology play a key role in the three major port regions of Texas: Beaumont-Port Arthur, Houston-Galveston, and Corpus Christi. While the Rainbow Bridge in Port Arthur, opened in 1938, still remains to be the tallest bridge in Texas, the new Houston Ship Channel Bridge, as well as the new Harbor Bridge in Corpus Christi, are currently under construction.[102] Both of these projects are directly linked to the petrochemical activity in the respective areas. Billions have been and are being invested into large infrastructural projects that connect cities across industrial fields on land and water. The adaptation of urban infrastructure to accommodate the new era of crude carriers and vessels will allow for a further expansion of petrochemical facilitates and cargo activity in Texas. These infrastructural investments, often financed by federal or state funds, are part of city planning for the hydrocarbon economy. While smart concepts on urban watersheds and storm protection often seem absent, projects to ensure further growth of Texas oil seem on the rise. Again.

> *The dialogue between architecture and the (cultural) environment is manifested through the physical relationship to the ground. As rising sea-levels, storms and changing ecological conditions shift the edges of water and land, of habitable surface, architecture needs to renegotiate the relationship between object (building) and datum (land or water).*

102 See TxDOT, “Project Profile: US 181 Harbor Bridge.”

> *Land, as an entity, has the power to articulate authority, it provides resources and grounds architecture, metaphorically and literally, by tying environment and architectural creation together.*

The physical analysis of a place starts with the very surface, the basis of architectural creation: land. Architecture as a phenomenological discipline must include the natural beyond the built environment and more: *"drifting clouds, night and day, as well as feelings"* according to Christian Norberg-Schulz.[103] The relationship between building and land demands to be renegotiated in a time, where changing weather patterns shift the edges of land and water and, hence, change the foundation of physical creation. Texas' coastal cities define a particular typology of human settlements, shaped by the economic power of fossil fuels. The "Coastal Oil City" as a typology of Texas is a physical manifestation of an economy-driven political regime, building cities against and not with nature.

> *"[...] the city emerges as a locus of a permanent political conflict of which architectural form is one of the most extreme and radical manifestations."*[104]
>
> *- PIER VITTORIO AURELI, CITY AS POLITICAL FROM*

The elements of the coastal oil city typology are strongly connected to the natural landscape. Understanding landscape as the interface between natural habitat and cultural production enables the common ground of logistical operations that have formed the coastal territory over time. The spatial impli-

103 See Norberg-Schulz, "Genius Loci: Towards a Phenomenology of Architecture.", pp. 6-10
104 Aureli, "City as Political Form: Four Archetypes of Urban Transformation." pp. 32-37.

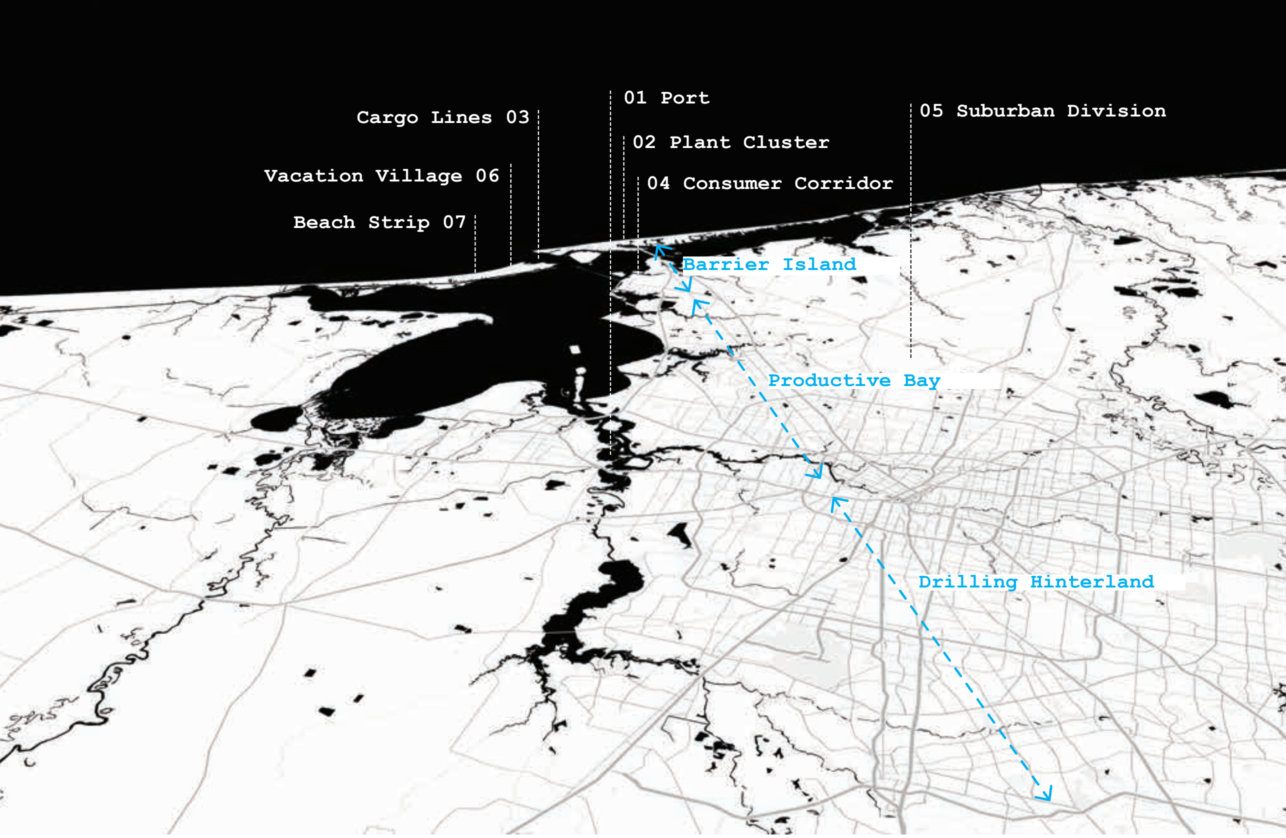


Figure 46. The coastal oil city in Texas is divided into three areas, the (1) Barrier Island, (2) Productive Bay, and (3) Drilling Hinterland. The major elements of this typology are the (1) Port, (2) Plant Cluster, (3) Cargo Lines, (4) Consumer Corridor, (5) Suburban Division, (6) Vacation Village, and (7) Beach Strip. (Created with Mapbox)

cations of petrochemical production along the Texas Coast are a manifestation of the industrial age enabling a global logistics landscape. A closer look at the elements of this urban typology undoubtedly starts with the geographic location. These location factors combine freshwater supply from rivers, a slightly protected settlement zone set back from the coast in a bay, and access to the Gulf of Mexico and the world. Building upon the advantages of the coastal lands, colonial settlers started the formative process of a new typology. The morphology of the landscape builds upon three primary types: the (1) Barrier Island, (2) Productive Bay, and (3) Drilling Hinterland. The Bar-

rier Island provides shelter from the risk of coastal storms. It is a high-performance storm mitigation device engineered by nature. The Productive Bay is the driver of the coastal ecosystem and the medium between fresh-and saltwater sources. The Drilling Hinterland is seamlessly attached to the coast. It is the breeding ground for resource extraction and harvesting. Within these three different types of landscapes, the elements of the coastal oil city serve as drivers for spatial development. These elements include the (1) Port, (2) Plant Cluster, (3) Cargo Lines, (4) Consumer Corridor, (5) Suburban Division, (6) Vacation Village, and (7) Beach Strip. The core element of the coastal oil-city is the port. As a hub for trade and commerce, the port can be seen as the economic backbone of this type of city. It is a significant employer and economical source of income. Alongside the port comes the plant cluster, which refines, processes, and stores petrochemical products. Both the port and plants could not operate without the logistics network that enables the supply and distribution of products on land, water, and air. Arranged like a typical linear city in the United States, the Consumer Corridor feeds the Suburban Division as a residential type of settlement. Lastly, the Vacation Village is an economic engine of growth, fueled by the Beach Strip as a permanently accessible public space for leisure and recreation.

While Texas' coastal cities have been growing slowly, or some have even been even shrinking, over the past thirty years, oil has once again become an engine of growth.[105] However, a potentially unsustainable growth as the history of industrial cities failing to diversify their economic portfolio, have shown. While first access to water and fertile land was essential to human settlements, it soon became commodities, like salt, silver, gold and ultimately fossil fuels, which ensured economic growth over a certain period of time. Cities like Detroit demonstrate how urban environments need to adapt to a changing economy to be successful – or risk failure. American industrial cities lack a variety of different economic branches across all salary ranges and

105 See Census Bureau, "Texas."

become vulnerable socioeconomic entities. As the global trends towards a Post-Industrial service-oriented society create new opportunities in how we might think and rethink settlement strategies and the development of cities, the reality along the Texas Coast is different: the new Texan realities are old. They are shaped by global corporations, extracting precious resources faster and in a quantity unseen before. The coastal landscapes of Texas are still largely undeveloped. Even though wind farms have become a new type of coastal energy, shaping the landscape in addition to refineries and oil derricks, the long-term impact of burning a dark liquid, is going to be one of the most influential physical parameters to rethink where to build, rebuild or relocate human settlements.

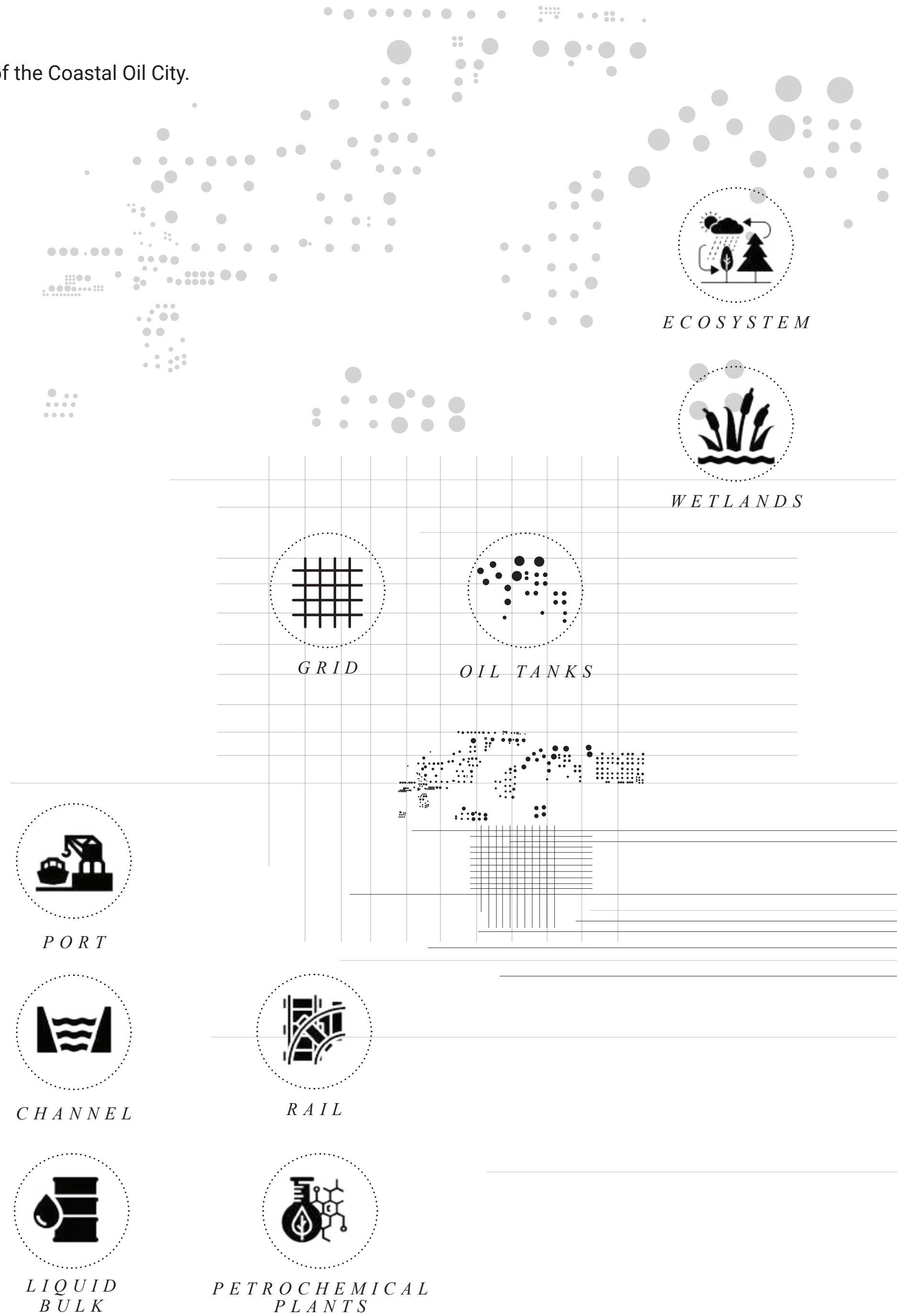
> *"Every society - and hence every mode of production [...] produces a space, its own space."*[106]
>
> *> HENRY LEFEBVRE: THE PRODUCTION OF SPACE, 1974*

The Texas Coast, as geopolitical territory, will likely remain to be a petroleum super-power for decades to come. It will also remain to be at the forefront of suffering the consequences of global warming fueled by oil. The spatial regime of burning fossil fuels produced a type of coastal city, that in itself produced a particular urban space within and around oil production. After this late oil boom, a variety of Texas' coastal cities are at risk of becoming the Detroits of tomorrow: former industrial cities that will have failed to adapt to economic and cultural shifts and most importantly to (climate) change. And while the transition into a Post-Oil Environment has started globally, oil-producing cities need to accept a new world: adapting to the consequences of decades of fossil-fuel-burning and (re)building a sustainable energy landscape within and around the city. An initial step to climate adaptation of the built environment can be identified by understanding the elements that could

106 Lefebvre, The Production of Space. p. 31

transform the typology of the coastal oil city into a post-oil city. This transformation involves the architecture of the city as a fundamental pillar, yet relies on each member of the urban ecosystem to contribute. From the Barrier Island, across the Productive Bay, to the Drilling Hinterland, the natural, cultural, and built environment are subject to change. Moving from the urban to the architectural scale, a typological approach to climate adaptation of architecture and the city is outlined on the next pages to show how the architectural object could renegotiate its relationship to the ground.

Figure 47. Elements of the Coastal Oil City.




VACATION VILLAGE
SUBURBAN DIVISION
HIGHWAY

04

Typological Adaptation

(en)Visioning a
Disciplinary Approach

04

Architectural Scale

TYPOLOGICAL ADAPTATION

(en)Visioning a
Typological Approach

Typological approaches are utilized in almost any discipline to establish a classification of organisms, objects, methods or processes into groups with shared characteristics. Similarly, urban typologies can be classified. This work proposes five major categories to define architectural typologies based on context, form, function, materiality, structure, and performance. As anthropogenic climate change shifts the edges between water and land, this work urges context as the primary premise for adaptation as the physical conditions that form the basis of architecture and the city have started to change. In particular, the formal relationship between the architectural object and its reference surface, water or land, can be utilized to develop a typological approach to architectural and urban adaption. Therefore, typological adaptation may be utilized as a method for climate adaptation of the built environment, aiming to articulate a disciplinary response of architecture to this pressing environmental crisis.

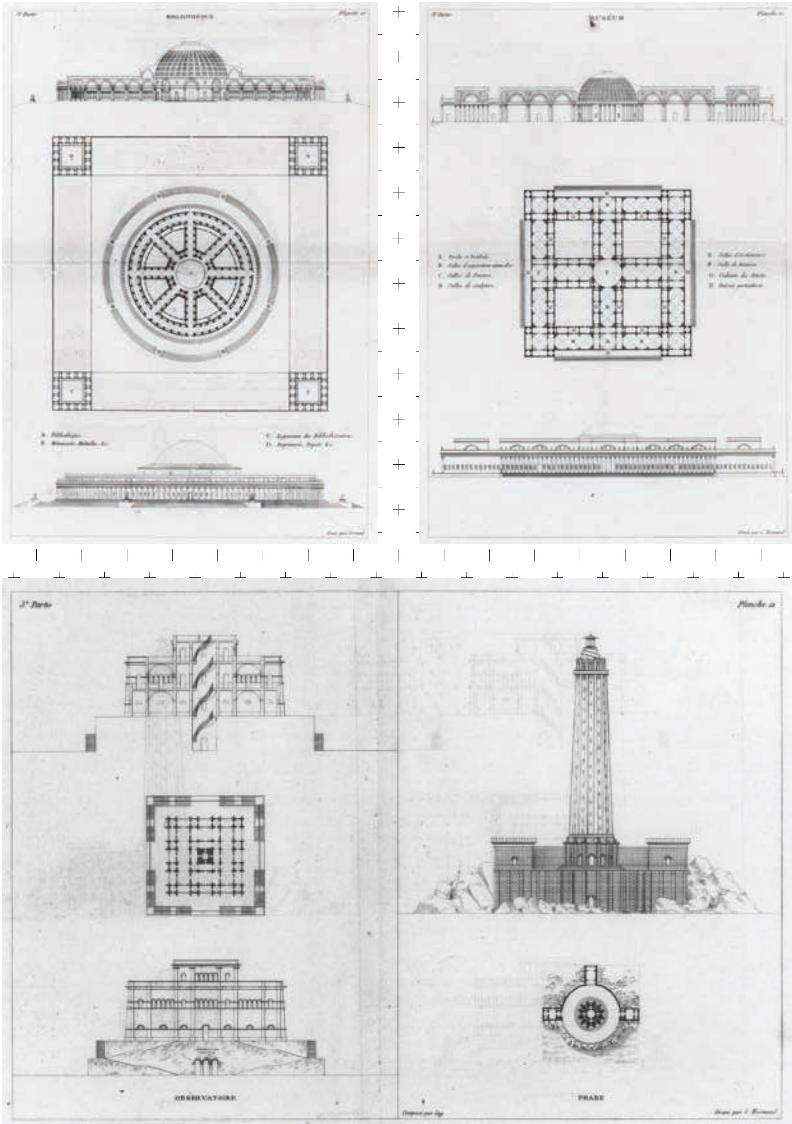


Figure 48. Jean-Nicolas-Louis Durand, ca. 1800 Elements of Buildings, systemathique design. (Images: Durand, "Précis of the Lectures on Architecture." pp. 48-49)

Typology in architecture most commonly refers to the functional reduction of buildings into groups like museums, housing, theaters, etc. In that sense, typology is a simplistic approach to classifying buildings into categories based on only one parameter, which reduces the complexity of an architectural object to its functional use. Typology may also describe formal aspects of buildings to develop groups like towers, slab or mat-buildings, etc. Referring to a building type based on overall proportion excludes the functional component of classification and relates buildings by tectonic similarities. Another example of a formal building type is the courtyard typology. It does not describe the function or purpose of the architectural object, nor does it describe the tectonic proportions, but rather the internal solid-void relationship as the building contains an enclosed exterior space. Typology, as an attempt to classify architectural objects, suggests that these objects may be grouped into any category as long as certain key parameters or rules define and enable the categorization of an object.

4.a
PROPOSING TYPOLOGY AS A METHOD: A DISCIPLINARY APPROACH

The etymological origins of the term typology derive from the Greek *'typos'* for *'type'* and the suffix *'ology'* which refers to a *'study of.'* Typology can, therefore, be summarized as the *'study of types.'*[1] More broadly, typology can also be understood as the discourse, theory, science, or *'method of type'*.[2] These definitions underline that typology is more than the classification of buildings based on predefined parameters but may be understood as a methodological approach towards architecture and the built environment.

1 See Cambridge Dictionary, "Typology."
2 Cf. Lee and Jacoby, "Typological Urbanism and the Idea of the City." pp.17-18

In architectural history and theory, the term typology has played a significant role, spanning from the origins of architecture, across the early days of industrialization, to the contemporary discourse. In his writings of 1825 titled *'Dictionnaire d'architecture'* (Dictionary of Architecture), Antoine-Chrysostome Quatremère de Quincy elaborates on the concept of *'type and model'* highlighting the generic qualities of type versus the specific model.[3]

> *"The word 'type' represents not so much the image of a thing to be copied or perfectly imitated as the idea of an element that must itself serve as a rule for the model [...]. The model, understood in terms of the practical execution of art, is an object that must be repeated such as it is; type, on the contrary, is an object according to which one can conceive works that do not resemble one another at all. Everything is precise and given in the model; everything is more or less vague in the type. Thus we see that the imitation of types involves nothing that feelings or spirit cannot recognize [...]."*[4]
>
> *> ANTOINE-CHRYSOSTOME QUATREMÈRE DE QUINCY: DICTIONNAIRE D'ARCHITECTURE*

Therefore, understanding the concept of type in architecture requires to understand the concept of a model as a specific application of a generic type, in a specific place, and therefore exposed to specific contextual conditions. When Aldo Rossi later rephrases this exact passage of de Qincy's work, he describes the '*rule*' as *"the structuring principle of architecture."*[5] Rossi also stresses that the properties of a type cannot be further reduced and therefore describe the essential character of a type. He summarized the type as *"the*

3 Cf. Rossi, The Architecture of the City. p. 40
4 Ibid.
5 Ibid.

very idea of architecture that which is closest to its essence."[6] The concept of the architectural type represents a disconnect between type and form. Form as a component of architecture is applicable to the model but not the type. The unifying rules which establish a type are unrelated to the physical appearance, or Gestalt of an object.

A few years prior to de Quincy, Jean-Nicolas-Louis Durand had addressed typological questions in his book *'Précis des leçons d'architecture données à l'École royale polytechnique.'* For Durand, the architectural type is the counterpart to taxonomy in the life sciences. His theory relates the classification of living organisms into species in the fields of biology, botany, and zoology to the classification of buildings into types. The transformation of the architectural type could be seen like the mutation within plants or animals. Much like evolutionary processes that enable the adaptability of certain species based on external conditions, architectural types can change over time: some become more important, some obsolete, and some can be transformed or form new types.[7] For Durand, types evolve based on shifts in society or changes in site conditions. Abstract, diagrammatic representations of building types based on precedents, classification, taxonomy, repetition, differentiation, and reinvention constitute typological work.[8] In that sense, artificial types may behave like their organic counterparts: species. Durand's work on the types or 'elements' of architecture also largely relied on proportional systems linking aesthetic principles to typological investigations. The aim to find geometric 'rules' originating from nature, so they can be applied to architecture, has been a task conducted throughout centuries, from Vitruvius to Le Corbusier.[9] If typological studies in architecture relate to the concept of classification based on any predefined parameters, it is certainly valid to establish a typology based on aesthetic principles of geometry. The question remains whether such studies can be empirically proven, or not, which ultimately led to the disciplinary critique of proportioning and ordering systems in the second half of the 20th century. Ernst Neufert's *Architect's Data, Bauentwurfslehre,*

6 Ibid. p. 41
7 Cf. Durand, "Précis of the Lectures on Architecture." pp. 48-49
8 See Lee and Jacoby, "Typological Urbanism and the Idea of the City." pp. 17-19
9 Cf. Durand, "Précis of the Lectures on Architecture." pp. 48-49

from 1936 was a modernist attempt to categorize the elements of architecture. Following a traditional Bauhaus approach, rationalizing design into predefined elements, Neufert's work can certainly be seen as typological.

The analogy between natural organisms and built, or artificial, objects has become particularly relevant over the past two decades as the emerging technologies of computation, generative design, and digital fabrication evolved into the organic world of biology. As the spatial regimes of the digital age (re)shape the built environment, the approach of pursuing built objects as assemblies rather than naturally grown organisms may be challenged. While some masterworks of 20th and 21st century architecture have used the term '*organic*' in different ways, from Frank Lloyd Wright to Hans Sharoun or Zaha Hadid, technological progress has enabled new formal languages of design and fabrication. With their pioneering projects, Frank Gehry and his team applied methods of computer-aided drawing and modeling (CAD/CAM) to architecture in the 1980s. The technology necessary for iconic curvilinear projects like '*El Peix'* in Barcelona, the *'Guggenheim Museum'* in Bilbao, or the *'Walt Disney Concert Hall'* in Los Angeles, originated in fields outside of architecture.[10] The complexity of double-curved surfaces required three-dimensional modeling in order to develop the necessary set of drawings for the manufacturing of panels and trusses. In the early stages of CAD/CAM software, architects had to utilize programs from aerospace engineering and from the automobile industry for the design development phase of a project. For the structural systems and especially for the manufacturing and assembly of projects like Gehry's '*DG Bank Building*' in Berlin, methods from the ship-building industry were applied to architecture and its new complex forms.[11] These new forms certainly can be seen as a new typology of buildings if grouped by formal aspects or means of generative design and digital manufacturing. However, in classical terms of typology, the computer-aided process changed the face and assembly of buildings more than the functional purpose. Suppose typology is approached as being disconnected from formal aspects. In that case, the types of design and the types of manufacturing and building assembly

10 Cf. Kolarevic, Architecture in the Digital Age: Design and Manufacturing. pp. 6-10
11 Ibid.

have been transformed. However, the architectural typology of a building itself cannot be impacted by changing design and manufacturing processes only.

Greg Lynn argues in his lecture titled ‘*Deviant Types: From a Typological to a Topological Architecture*’ in 1993, that all types in architecture are “*already depending on deviation and differences*.”[12] He breaks away from a static understanding of typology as unchangeable, referencing Palladio and Le Corbusier, and highlights the ability of types to change. Historically, the type is strongly related to the concept of geometry - of fixed and precise measurements and proportions. Lynn elaborates on the ideas of wholes and fragments, of bodies and geometries, to ultimately claim that the technological advances of three- or multi-dimensional modeling software allow architects to move away from rigid geometries and static types to topology.[13] Topology, as a mathematical concept, studies spatial relationships focusing on the parts of geometry that remain invariant under transformations like bending, stretching, or changes in size and shape.[14] Approaching typology in architecture through geometry or topology is a valid method to group objects by mathematical rules. After the historic understanding of types based on functional use, Lynn’s theory aligns more with defining groups of objects based on tectonic proportions. This approach expands typological studies from the two-dimensional to the three- and even multi-dimensional space of topological relationships. Neri Oxman summarizes *“the split personality of every designer and architect operating today between the chisel and the gene, between machine and organism, between assembly and growth, between Henry Ford and Charles Darwin.”*[15] The fundamental differences between growth and assembly are two different approaches to architecture. While assembly is based on the concept of addition, creating an object of many parts, growth is based on the concept of a constantly evolving single entity - as a process of becoming rather than being. In the process of evolution in nature, the term ‘*species*’ seems to be

12 Cf. Architectural Association, “Greg Lynn: Deviant Types: From a Typological to a Topological Architecture.”

13 Ibid.

14 Cambridge Dictionary, “Typology.”

15 Cf. TEDtalk, “Neri Oxman: Design at the Intersection of Technology and Biology.”

more appropriate than the word '*type*', underlining the natural origin of the respective entity. While we refer to groups of flowers or animals to be part of a certain species, we refer to groups of buildings or objects to be part of a certain type.

As Durand stated, taxonomy is a method that classifies elements into groups, based on specified principles. It is a concept applicable to both the natural and the artificial object - to species and types. Therefore, Oxman's comparison of Darwin's theories in Evolution and Ford's invention of the assembly line constitute the natural and artificial counterparts of '*development*' (of organisms) or '*production*' (of objects). The fusion of the worlds of natural organisms and built objects in the realm of digitalization affects almost every discipline. As described in the previous chapters, Klaus Schwab argues that we have entered the '*Fourth Industrial Revolution*.'[16] He explains the historical stages of industrialization, starting in the mid-18th century. A series of inventions around the steam engine enabled the First Industrial Revolution from 1760 to 1840. Technological progress and especially electricity formed the pathway into the Second Industrial Revolution around the turn of the century. The assembly line and the mass production of goods drastically changed human life. In the 1960s, developments in information technology led to the first digital and Third Industrial Revolution. The Internet, paired with the availability of affordable computers for individuals around the world, marked a new era of global networks. According to Schwab, we entered the Fourth Industrial Revolution at beginning 21st century. Building on the digital revolution, genome sequencing and nanotechnology enabled to merge physical, digital, and biological domains.[17] With the technology in place making 3D-printing of living cells possible, with new scientific methods of altering the DNA of any organism, with the fusion of mechanical body parts and the nervous system, humankind seems to have made the transition from assembly to growth and from types to species into the world of designed and engineered biology.[18] More than ever, the comparison between artificial objects and natural organ-

16 See Schwab, The Fourth Industrial Revolution. p.6

17 Ibid. pp. 7-9

18 Cf. Dade-Robertson, Figueroa, and Zhang, "Material Ecologies for Artificial Biology: Biomineralization and the State Space of Design." pp. 1-12

isms seems to be valid. Both Durand's and de Quincy's theories on typology deserve to be revisited given the timely context which highlights the importance of typology as a core element in the architectural discourse. Rafael Moneo published an article titled 'On Typology' in the summer of 1978. To him, *"type means the act of thinking in groups."*[19] Addressing the question of type, so Moneo, leads to questions on the architectural discipline itself. Similar to the metaphor of comparing types in architecture to DNA in biology, Moneo's link between type and the core of the discipline seems to be fitting.

> *"The very concept of type, [...] implies the idea of change, or of transformation. [...] The concept of type is in itself open to change, insofar as it means a consciousness of actual facts, including, certainly, a recognition of the possibility of change. By looking at architectural objects as groups, as types, susceptible to differentiation in their secondary aspects, the partial obsolescence appearing in them can be appraised and consequently one can act to change them. The type can thus be thought of as the framework within which change operates, a necessary term to the continuing dialectic required by history. In this continuous process of transformation, the architect can extrapolate from the type, changing its use; he can distort the type by means of a transformation of scale, he can overlap different types to produce new ones. He can use formal quotations of a known type in a different context, as well as create new types by a radical change in the techniques already employed. The list of different mechanisms is extensive - it is a function of the inventiveness of architects."*[20]
>
> *> RAFAEL MONEO: ON TYPOLOGY, 1978*

19 Moneo, "On Typology." p. 23
20 Ibid. p. 24-27

STATEMENTS ON TYPOLOGY
IN ARCHITECTURE

001
Type means the act of thinking in groups (Moneo)

002
Types in architecture are the counterpart of species in biology (Durand)

003
Models are applications of types (de Quincy)

004
Type and form are disconnected (Rossi)

005
Types can become obsolete (Durand)

006
Types can be transformed or form new types (Durand)

conclusion
Types can adapt to changing contextual conditions and can, therefore, undergo an evolutionary process of transfromation in response to climate change.

Figure 49. Statements on Typology in Architecture by Moneo, Durand, de Quincy, and Rossi.

While DNA contains the genetic code that physically defines a living organism, DNA also has the ability to mutate or change. Summarizing the ideas of de Quincy and Durand, Moneo describes the type's ability to change as inherently important. If typological studies in architecture are comparable to genome sequencing in biology, then types are the most basic principle of the architectural discipline. Types can be thought of as genomes, the elements within a type consist of DNA. Or, with a jump in scale, types can be seen equivalent to species, the elements of a species are based in their DNA.

> *"To understand the question of type is to understand the nature of the architectural object today. It is a question that cannot be avoided. The architectural object can no longer be considered as a single, isolated event because it is bounded by the world that surrounds it as well as by its history."*[21]
>
> *- RAFAEL MONEO: ON TYPOLOGY, 1978*

The following hypotheses summarize and synthesize the characteristics of *'type'* in an attempt to define *'typology'* as a method in architecture and urban design: (1) type means the act of thinking in groups (Moneo), (2) types in Architecture are the counterpart of species in biology (Durand), (3) models are applications of types (de Quincy), (4) type and form are disconnected (Rossi), (5) types can become obsolete (Durand), and (6) types can be transformed or form new types (Durand). Following these thoughts, it becomes valid that typology as a method in architecture can be utilized to categorize architectural objects with shared characteristics into specific groups. In order to simplify this approach by establishing six overarching groups that could serve as a basis of typological classification, this work introduces (1) context, (2) form, (3) function, (4) materiality, (5) structure, and (6) performance. These six groups

21 Ibid. p.44

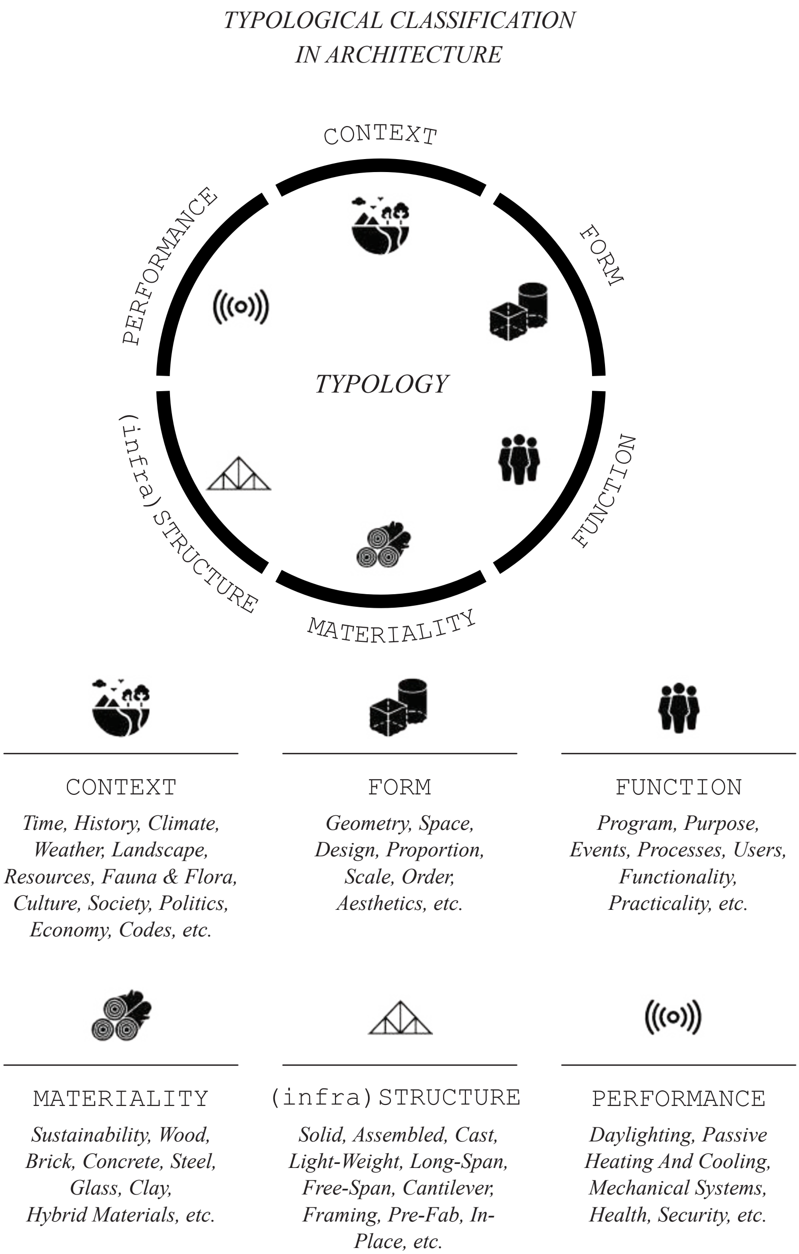


Figure 50. Typological classification in architecture based on context, form, function, materiality, structure, and performance.

summarize crucial characteristics of an architectural object, its parts, and its relationship to the environment.

Context describes the natural, cultural, and built environment the respective project is part of. These criteria range from the topography and landscape, societal and cultural patterns, to the physical surroundings, including existing buildings and infrastructure. Form summarizes the geometry-based characteristics of an architectural object, including its spatial, proportional, tectonic, and aesthetic appearance as an artistic design object. For example, a building could be classified as a tower, describing its proportion, or as a courtyard building based on the tectonic qualities of a building mass that encloses a void space. Function outlines criteria based on uses and programs set as inherent features of the respective project, reaching from spaces of assembly, individual or collective programs, or more traditional approaches focusing on residential, commercial, cultural, etc. Materiality-based groups can be based on the materials used for construction, e.g. timber buildings, brick walls, or glass facades would fall under this category. Structure summarizes systems and methods of construction, for instance, pre-fabricated, light-weight, framed structures, etc. Lastly, performance combines characteristics, like mechanical systems, daylighting, passive heating, cooling, etc.

This concept proposes no particular sequence yet claims that all six categories are addressed in any physically built project, intentionally or unintentionally. For instance, Paula wants to build a sphere-shaped space that ultimately ends up being a pre-fabricated timber construction in a rural context utilized as a museum. Meanwhile Paul wants to design a museum that will be a sphere-shaped, pre-fabricated timber construction in a rural context. Simultaneously, Christian aims to build a pre-fabricated museum and chooses timber over steel given the rural context of this sphere-shaped design, while Christina is exploring what building fits best into the rural context of her neighborhood and ends up developing a sphere-shaped, pre-fabricated timber construction. Regardless of the initial idea or premise of the project, all categories will be addressed. Typology can, therefore, be utilized as a method for architectural design. Understanding what type of project one is dealing with is a crucial first step in the design decision-making process. Similar approaches apply to both the architectural object and the city as an aggregate of types. While the architectural object is primarily concerned with the relationship of its parts to one another and to its surroundings, the urban scale focuses on the relationship between those objects and the organisms that occupy and travel through these in-between spaces.

> *"Rossi used typological knowledge in order to empirically represent these structural and formal aspects of the city. In this sense, urban morphology was not a simple formal rendering of the urban fabric, but the envisioning of the logical structure of relationships through which the city as a whole evolves. According to Rossi, identifying this logical structure of relationships would not transform them into general and totalizing statements."*[22]
>
> *> PIER VITTORIO AURELI, THE DIFFICULT WHOLE*

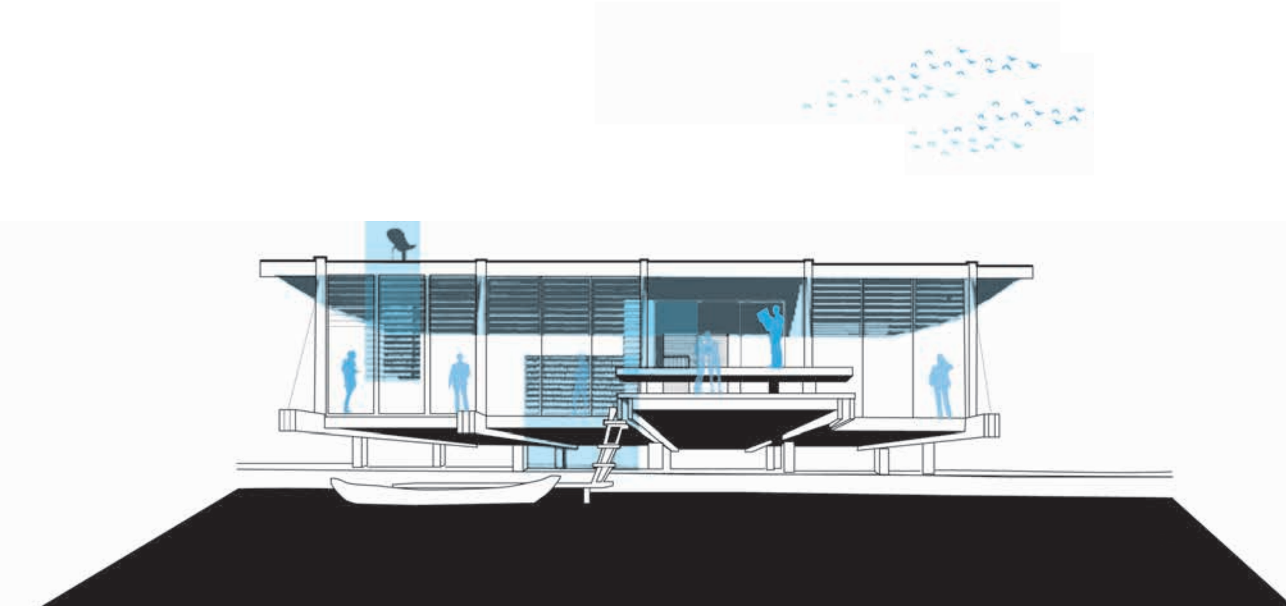
In the age of climate change, particular attention must be drawn to contextual conditions. On both the scale of architecture and the city, environmental changes demand a sectional design response as the relationship between object and ground is fundamentally a vertical relationship. Therefore, this work applies typology as a design method to group architectural objects by their sectional relationship to the ground.

22 Aureli, “The Difficult Whole.”

4.b.
UNDERSTANDING ARCHITECTURAL ADAPTATION: CLIMATE CHANGE AS A VERTICAL PROBLEM

The climate crisis creates a series of threats to urban environments. In coastal regions, many climate change impacts are related to the ground elevation and are, therefore, a vertical problem for the architecture of the city. Coastal regions have historically developed a series of types, vernacular to the local climate. These types can, therefore, be seen as responsive to environmental conditions. Buildings on stilts and other structures elevated from the ground on posts can be found in many coastal areas throughout history. These vernacular typologies understood flood impacts as a vertical problem demanding that architects respond with a sectional solution.

Figure 51. The Cocoon House by Paul Rudolph was an attempt to appropriate modernist principles to subtropical environmental conditions. The structure is elevated from the ground and applies several strategies for natural cooling. Rudolph's design approach can be described as typological, as he changed the object-to-ground relationship. (Diagram appropriated from Domin and King, Paul Rudolph: The Florida Houses. p. 21)



Along the Gulf of Mexico, pre-colonial architectural typologies, like the Chickee Hut[23] in Florida, used elevation as a typological strategy. The Chickee Hut is an elevated structure on posts, particularly fitting to a coastal wetland.[24] Such pile dwellings can be found along lakes and coastlines from Asia to Africa and from Europe to Australia, often dating back to prehistoric times.[25] In the first half of the 20th century, a group around Paul Rudolph from the Sarasota School of Architecture developed the iconic Cocoon House,[26] an example of modernist architecture responding to the climatic conditions of Florida. Certainly, urban pile structures like Venice or in parts of the Netherlands can be seen as a transscalar approach to apply object-scale strategies to urban-scale structures. In practice, gigantic urban fields in the United States have been developed applying non-responsive object-to-ground typologies. Along the Texas Coast, many buildings are built on a slab foundation, while few are elevated off the ground. However, the Federal Emergency Management Agency (FEMA) has released a series of recommendations and guidelines for raising structures in response to increased flood risks in recent years.[27]

As summarized in the previous paragraphs, types have the ability to change. While certain elements of a type have remained the same throughout centuries, adaptability is a fundamental characteristic of a type as changing context requires a typological response. Similar to the evolution of natural organisms, architectural types evolve too. Approaching type not as a stagnant, unchangeable entity but as continually evolving and responding to contextual change, brings significance to type as a concept in the age of climate crisis. Carbon emissions have fueled global warming. As glaciers melt and sea levels rise, as human-made storms get stronger and more frequent, as some areas drown while others experience drought, it has become clear that in the most extreme ecological change period since the beginning of civi-

23 See Dilley, Thatched Roofs and Open Sides: The Architecture of Chickees and Their Changing Role in Seminole Society.
24 Ibid.
25 See UNESCO, United Nations Educational, “Prehistoric Pile Dwellings around the Alps.”
26 Cf. Domin and King, Paul Rudolph: The Florida Houses. pp. 19-21
27 See FEMA, “Elevating Your House.”

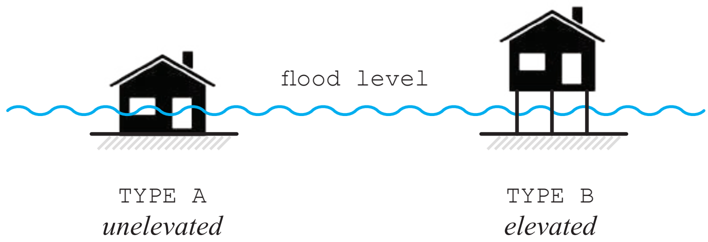


Figure 52. Building types in flood zones: unelevated vs. elevated.

lized human settlements, types need to respond. The datum as a reference surface is one of architecture's most fundamental principles. This reference surface has formed the basis of the architectural design process going back to antiquity. In the world outside the drawing board, the sketchbook, the modeling software, or the 3D-model, this reference surface can only be one of three things: water, ground, or, in rare cases, a human-made surface like other buildings. More abstractly, the notion of gravity can be described as a datum also, as flying objects or objects floating in outer space may not be related to a permanent reference surface, at least temporarily. In the vast majority of cases, the most significant reference surface for architectural creation, however, is ground and, to a lesser extent, water. While the term ground describes the earth's surface more generally, the term land is more specific. In its very basic definition, ground is described as "*the solid surface of the earth*," while land is described as *"an area of ground especially in terms of its ownership or use."*[28] In that sense, the term land requires a certain level of human activity imposed onto ground. This is what has happened in humanity's history: people are trying to alter the earth's surface, changing its ecosystems, harvesting its resources, and polluting air, water, and soil in a continuous process of reshaping ground into a productive resource landscape.

28 Cambridge Dictionary, "Ground."

Figure 53. A coastal neighborhood located in Ingleside on the Bay in Texas, partly protected by a breakwater

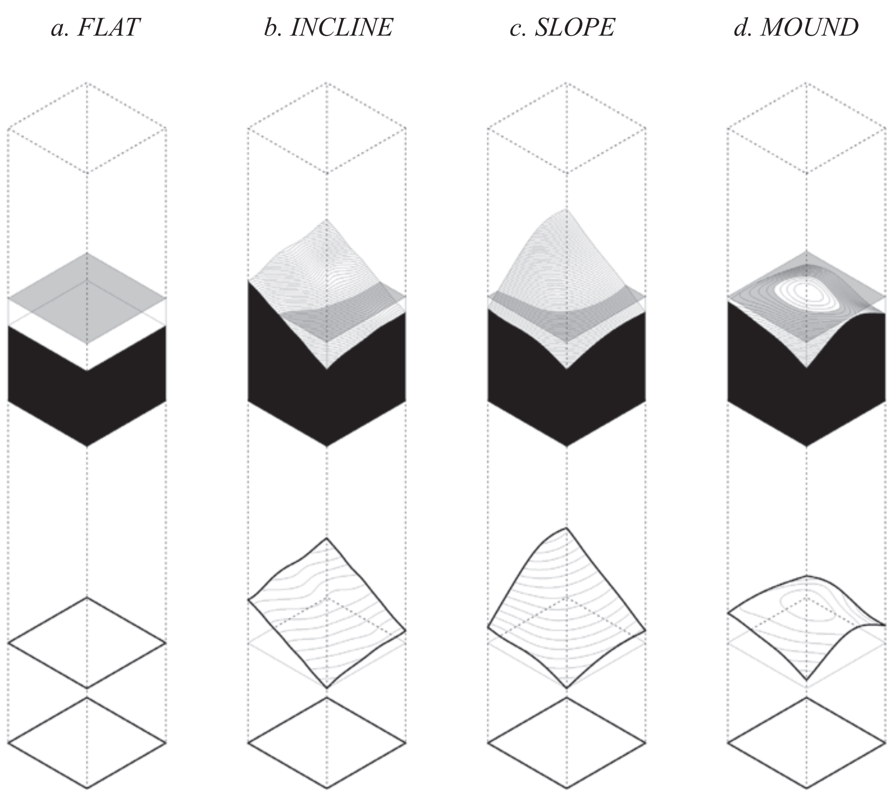

STOP

Figure 54. Street-view in Ingleside on the Bay, Texas, showing the proximity of sea-bound petrochemical vessels and residential neighborhoods.

Figure 55. Elevated building in Port Aransas, Texas.

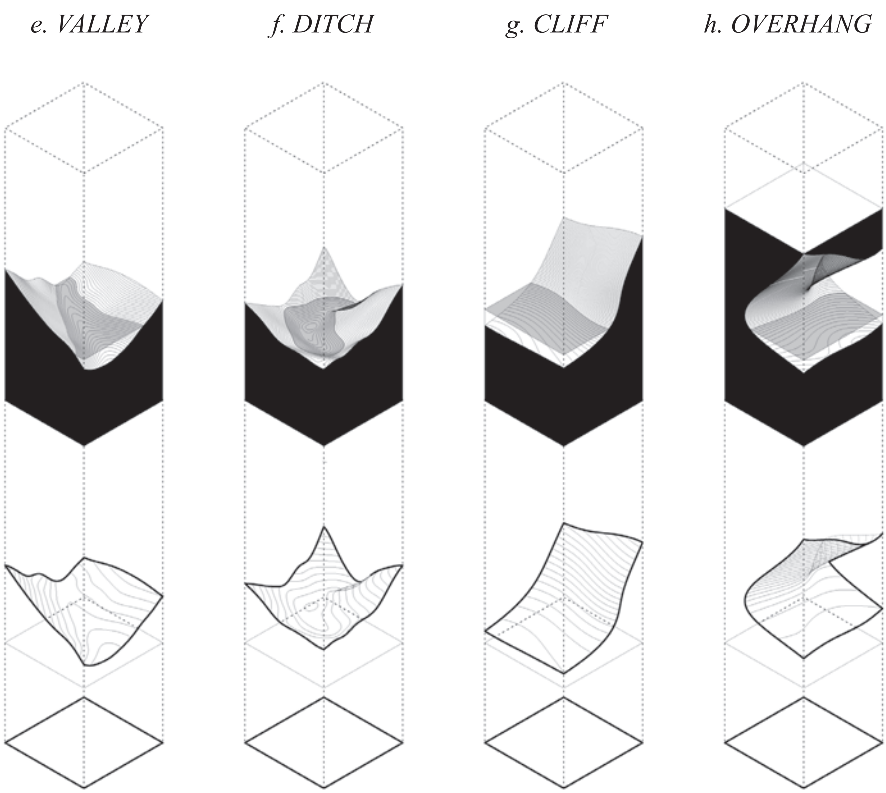
On the following pages, a series of twelve types are introduced in an attempt to classify relevant object-to-ground relationships in times of global climatic change. These types are labeled (a) Grounded, (b) Excavated, (c) Underground, (d) Elevated, (e) Raised, (f) Extended, (g) Mobile, (h) Flying, (i) Floating, (j) Submerged, (k) Protected, and (j) Enclosed. They constitute a group of architectural objects summarized by their sectional relationship to the ground. Each type is briefly described on the next pages. A series of eight landscape conditions highlights the respective type's capabilities and limita-

Figure 56. Landscape conditions have been summarized as (a) Flat, (b) Incline, (c) Slope, (d) Mound, (e) Valley, (f) Ditch, (g) Cliff, and (h) Overhang.

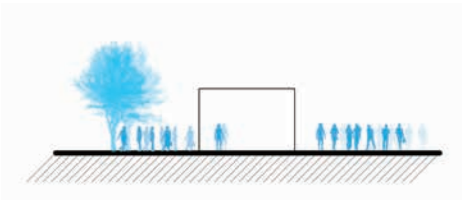


tions in response to certain topographies. The landscape conditions have been summarized as (a) Flat, (b) Incline, (c) Slope, (d) Mound, (e) Valley, (f) Ditch, (g) Cliff, and (h) Overhang. Furthermore, each types' adaptability to the respective condition is shown through highlighted icons. The adaptability of this series of types refers to the ability of each type to respond to the sectional impacts of climate change in relation to the ground. Lastly, a precedent is listed for each type to showcase that typology is simply a method to (re) group objects based on predefined characteristics.

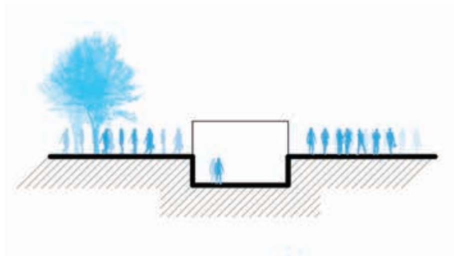
Figure 57. The following figures, graphics, and images on pages 165-178 explain the respective object-to-ground typologies. All images have been appropriated from open-source images platforms.



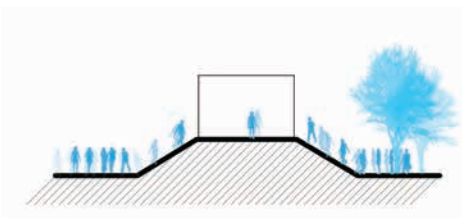
a. GROUNDED



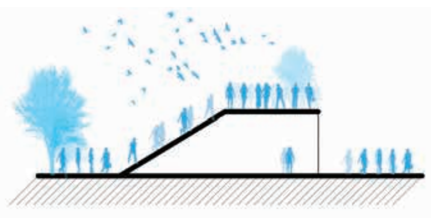
b. EXCAVATED



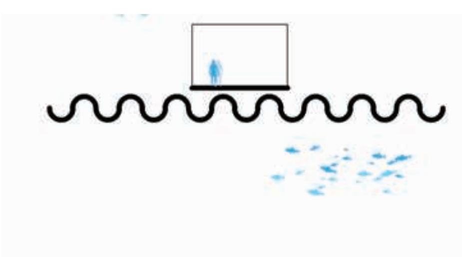
e. RAISED



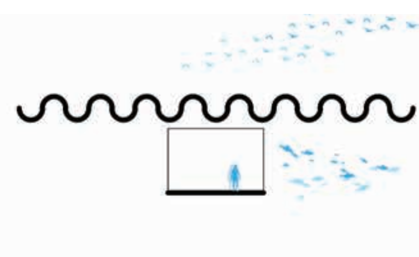
f. EXTENDED



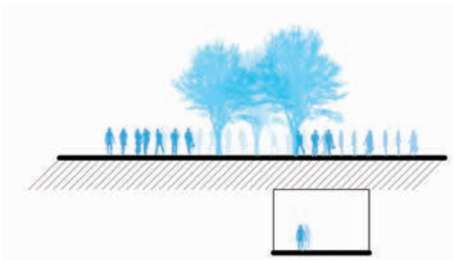
i. FLOATING



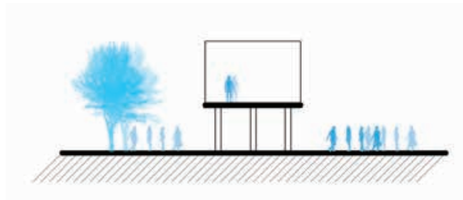
j. SUBMERGED



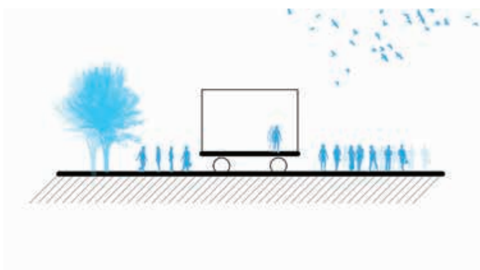
c. UNDERGROUND



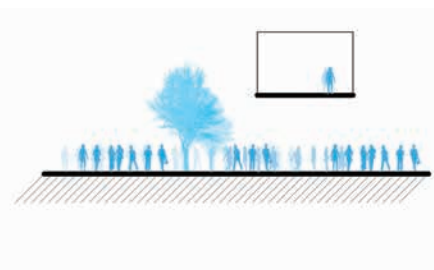
d. ELEVATED



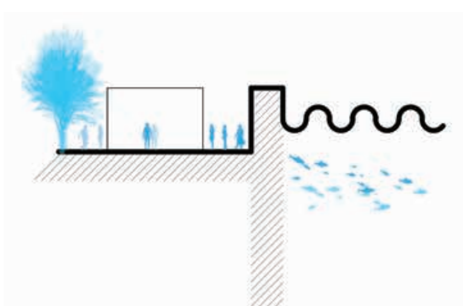
g. MOBILE



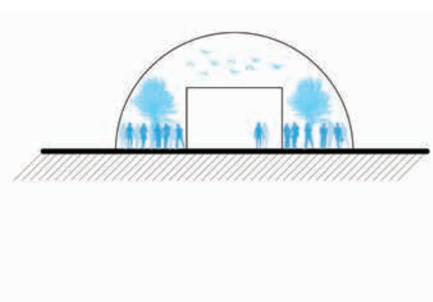
h. FLYING



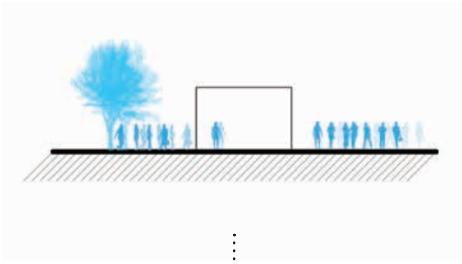
k. PROTECTED



l. ENCLOSED



a. GROUNDED

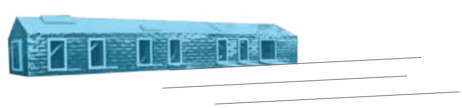


OVERVIEW

The *"Grounded Typology"* summarizes one of the most common object-to-ground relationships. This typology describes buildings simply connected to the ground with little to no alteration of the existing landscape.

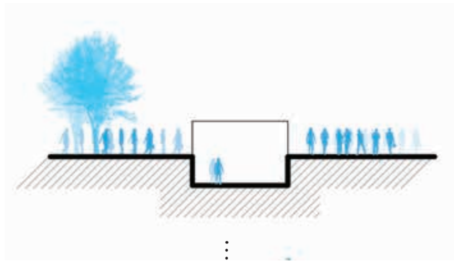
CONDITIONS

PRECEDENT



Balancing Barn
Suffolk, United Kingdom
MVRDV
2010s

b. EXCAVATED

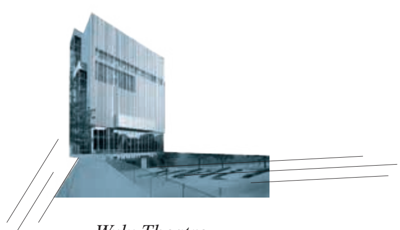


OVERVIEW

The *"Excavated Typology"* describes an object-to-ground relationship with a substantial amount of excavation being needed to insert major building parts into the ground. In this typology, the subtraction of solid mass in the ground enables the void space needed for the building.

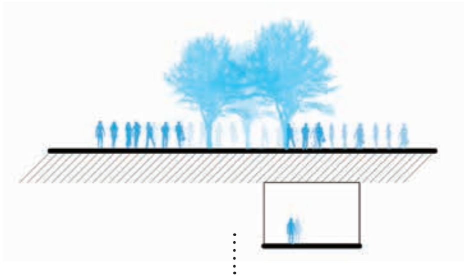
CONDITIONS

PRECEDENT



Wyly Theatre
Dallas, Texas
Joshua Prince-Ramus, Rem Koolhaas
2000s

c. UNDERGROUND

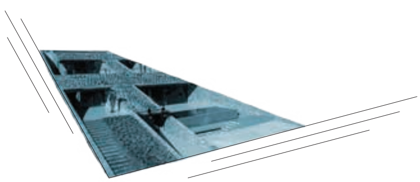


OVERVIEW

"Underground Typologies" describe structures with a mass located predominantly underground. This typology requires an almost equal solid-void relationship as the removed soil creates the structure's void space. Secondary elements of the structure may extend above ground.

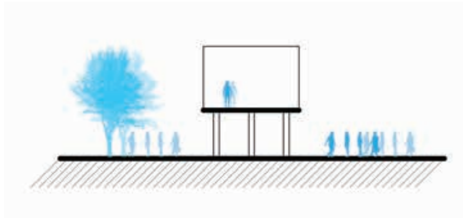
CONDITIONS

PRECEDENT



NCaved
Serifos, Greece
Iliana Kerestetzi, Mold Architects
2020s

d. ELEVATED



OVERVIEW

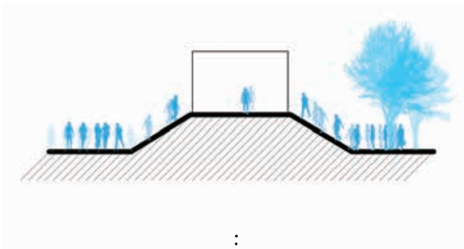
"Elevated Typologies" are disconnected from the ground due to structural elements like pillars or secondary building parts. This typology allows for little interaction between the object and the ground and provides numerous opportunities to adjust the architectural object to different terrains and slopes.

CONDITIONS

PRECEDENT

Unité d'Habitation
Marseille, France
Le Corbusier
1940s

e. RAISED

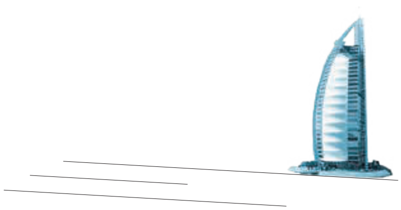


OVERVIEW

The "Raised Typology" places an architectural object on a higher elevation by changing the original landscape prior to construction. Natural materials like sand or soil are used to create a higher-grade elevation characterized by the relationship between object and ground as compared to the surroundings.

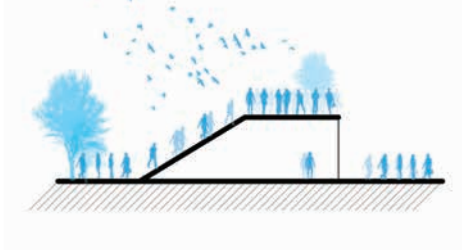
CONDITIONS

PRECEDENT



Burj Al Arab
Dubai, United Arab Emirates
Tom Wright
1990s

f. EXTENDED



OVERVIEW

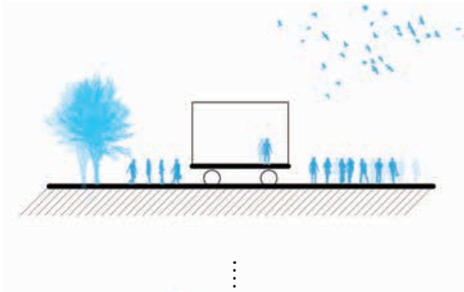
In the *"Extended Typology,"* the architectural object itself serves as ground. This topology allows the structure to become an extended part of the landscape, forming a hybrid that merges object and ground into one spatial entity by creating an artificial landscape.

CONDITIONS

PRECEDENT

Villa Rotonda
Vicenza, Italy
Andrea Palladio
1570s

g. MOBILE

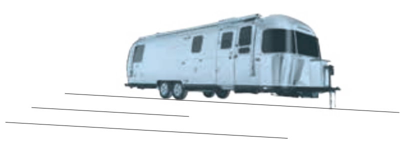


OVERVIEW

The *"Mobile Typology,"* describes moving objects with a temporary connection to a specific site. The object-to-ground relationship changes over time. Therefore, the architectural object responds to the respective surface condition and can permanently or temporarily change its location.

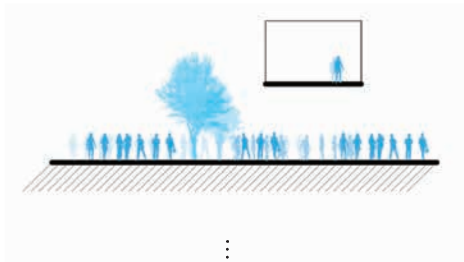
CONDITIONS

PRECEDENT



Airstram Travel Caravan
Los Angeles, California
Hawley Bowlus
1920s

h. FLYING

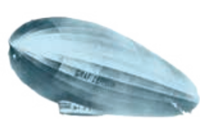


OVERVIEW

The *"Flying Typology"* defines flying objects, completely disconnected to the ground. The object-to-ground relationship can change permanently or temporarily. Depending on the specific object, a permanently solid surface may not be needed to enable this typology.

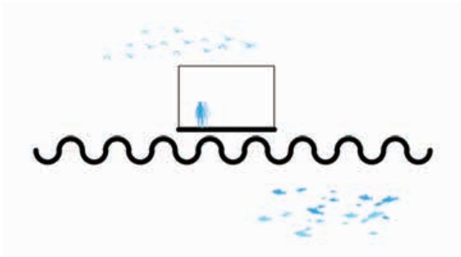
CONDITIONS

PRECEDENT



Graf Zeppelin Airship
Friedrichshafen, Germany
Ludwig Dürr
1920s

i. FLOATING

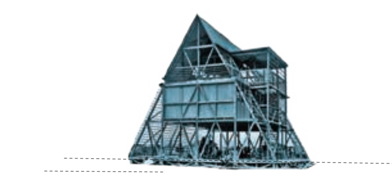


OVERVIEW

The *"Floating Typology"* describes architectural objects floating on water. The floating condition can be permanent or temporary. The water as a reference surface replaces the relationship to solid ground and allows the architectural object to either have a specific site or be movable.

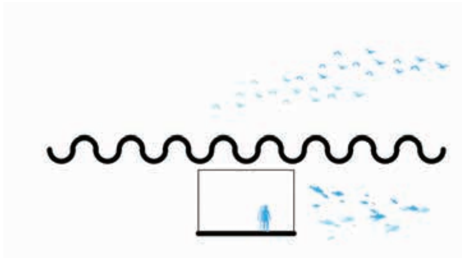
CONDITIONS

PRECEDENT



Makoko Floating School
Lagos, Nigeria
Kunlé Adeyemi, NLÉ Architects
2010s

j. SUBMERGED

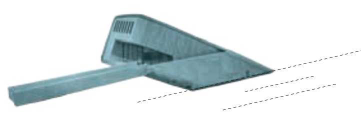


OVERVIEW

Architectural objects falling into the *"Submerged Typology"* category describe a condition in which the architectural object is permanently or temporarily under the water surface. Major parts of the object are covered by water, and there may or may not be a permanent connection to the ground.

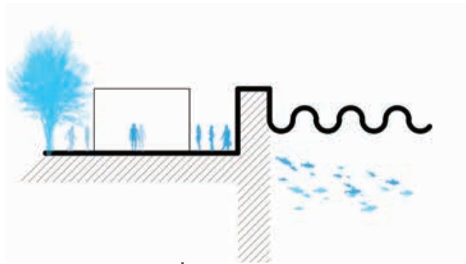
CONDITIONS

PRECEDENT



Under
Lindesnes, Norway
Snøhetta
2010s

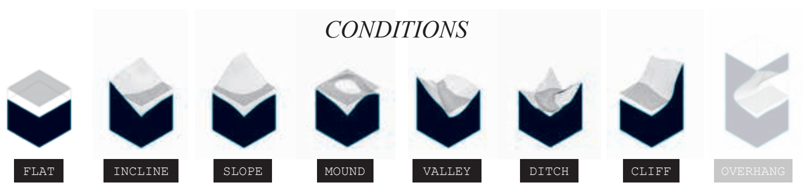
k. PROTECTED



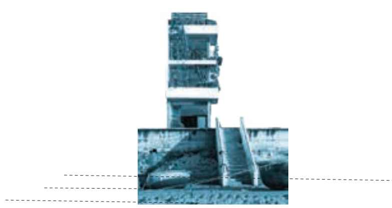
OVERVIEW

Infrastructural elements enable the *"Protected Typology"* and serve as a premise to maintain the respective architectural object in this specific site. The object-to-ground relationship varies based on the artificial conditions provided by the protective infrastructural element.

CONDITIONS

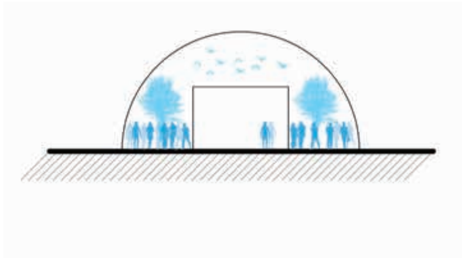


PRECEDENT



Coastal House
Vung Tao, Vietnam
Prana Architects
2010s

j. ENCLOSED

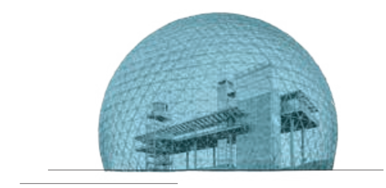


OVERVIEW

The *"Enclosed Typology"* describes architectural objects that are embedded into a microclimate and therefore detached from environmental impacts. The object-to-ground relationship becomes secondary, as the microclimate conditions provided by this type allow for almost any object-to-ground relationship.

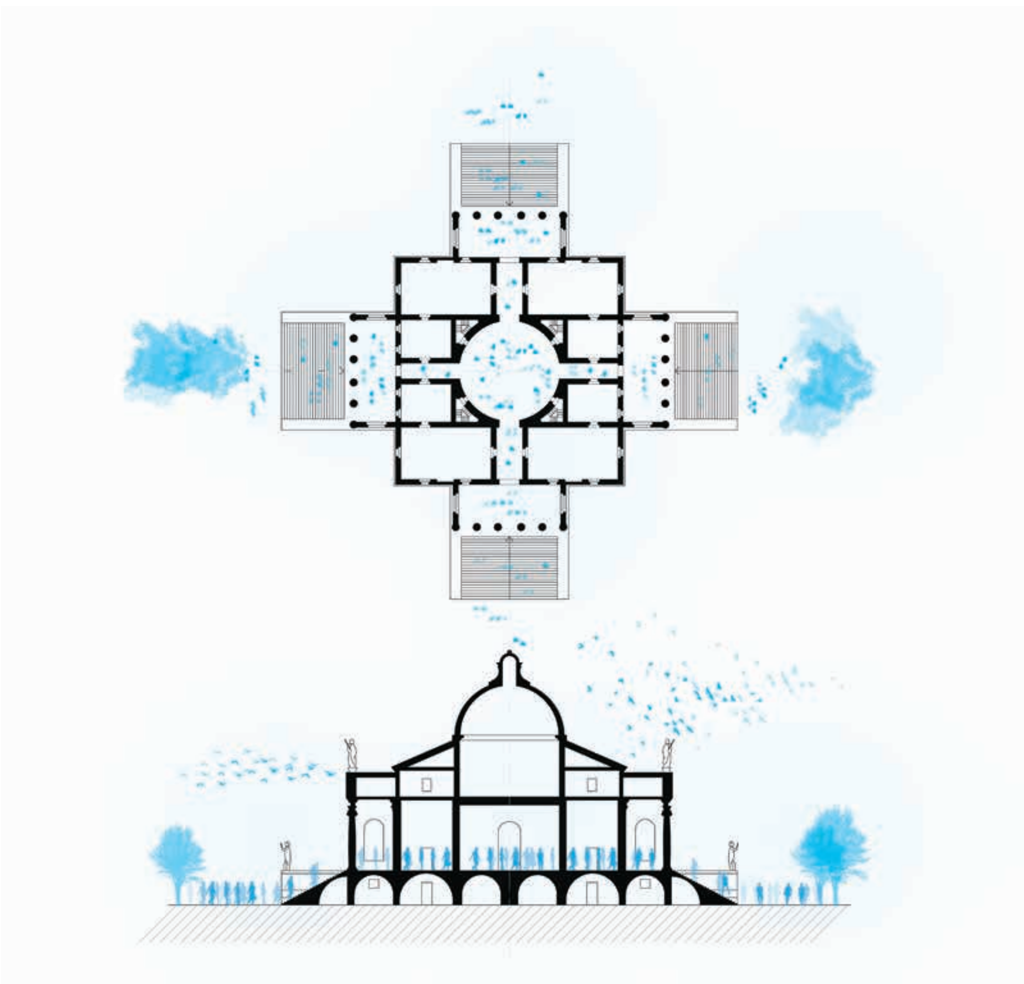
CONDITIONS

PRECEDENT



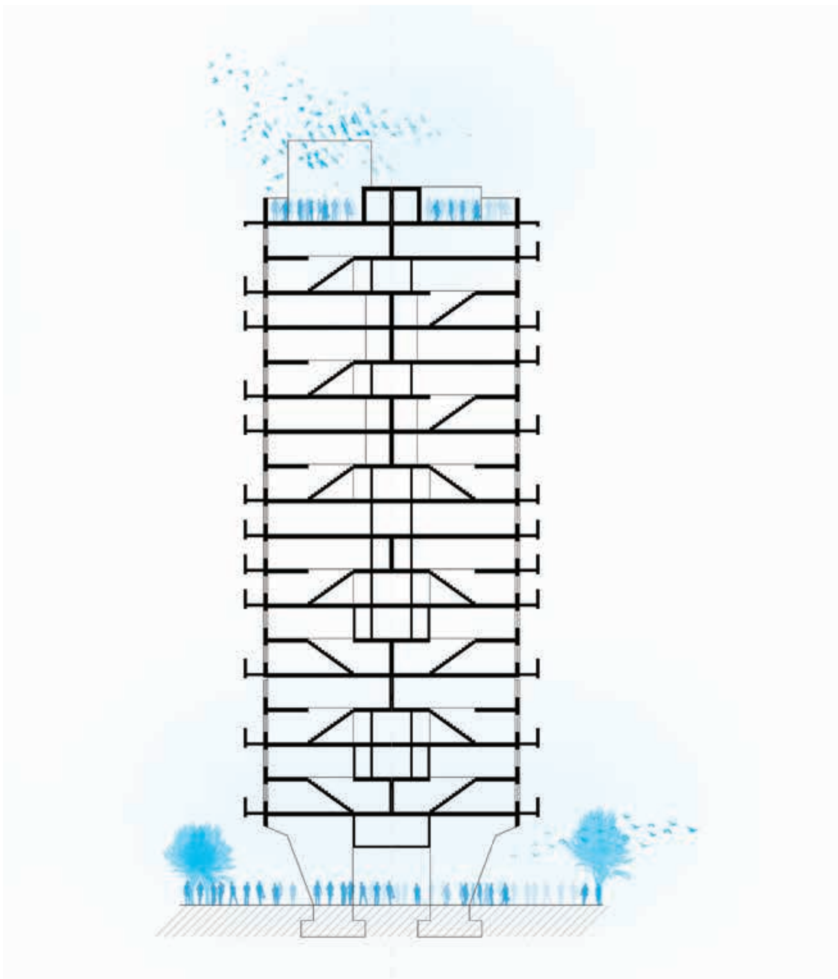
American Pavilion Expo 67
Montreal, Canada
Buckminster Fuller
1960s

This work does not claim to invent new types but rather to regroup existing types based on their adaptive capacity towards sectional climate change impacts, in particular flooding. Looking at *"Type d - Elevated"* and *"Type f - Extended,"* with the chosen precedents being Le Corbusier's Unité d'Habitation in Marseille, France and Andrea Palladio's Villa Rotonda outside of Vicenza, Italy, shows two fundamentally different object-to-ground relationships. Despite the projects' ideas not being related to environmental topics as a



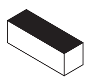
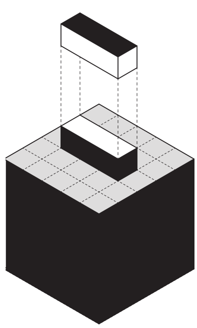
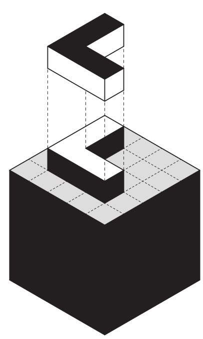
primary driver for the design, both buildings are negotiating a very distinct formal relationship to the ground. In Palladio's Villa Rotonda, the building itself serves as a plinth. It artificially creates a built landscape as an extension to the natural landscape into the interior space. The idea of the building on a plinth goes back to antiquity, with Roman and Greek temples often being elevated artificially. In times of global climatic changes impacting the ground condition, elevating buildings on a plinth as an extended landscape can con-

Figure 58. Drawings of Villa Rotonda (left), and Unité d'Habitation (right).



stitute a building type, as the relevance of the additional elevation of major spaces inside the architectural object might become a climate-responsive strategy in times of temporary flooding. In case of Le Corbusier's Unité d'Habitation, the harsh disconnect between the architectural object and the ground following some of the most fundamental concepts of the International Style movement,[29] also represents a successful strategy to the sectional problems imposed by increased flood risks. While neither Palladio nor Le Corbusier designed these buildings with climate change in mind, their projects can still serve as a conceptual prototype to address some of the most pressing formal questions combating climate change impacts.

29 Cf, Ebuz and Donatus, "How International Was International Style of Architecture?"

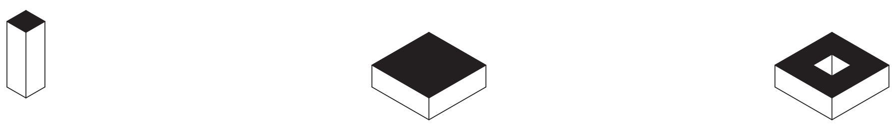
	LINEAR	*MULTI-LINEAR*
TYPE >		
DESCRIPTION >	*represents infrastructural and building types that are horizontally longer than their height*	*represents infrastructural and building types that combine several linear elements*
DIAGRAM >		

4.c.
DESIGNING WITH TYPES: TYPOLOGICAL ADAPTATION OF ARCHITECTURE AND THE CITY

As described on the previous pages, typology, or the study of types, is a method that aims to categorize objects and organisms by shared characteristics. The categories of context, form, function, materiality, structure, and performance introduced in this work aim to include a majority of aspects relevant to the architectural design discipline. Approaching climate adaptation as a

Figure 59. Axonometric drawings of five selected formal types.

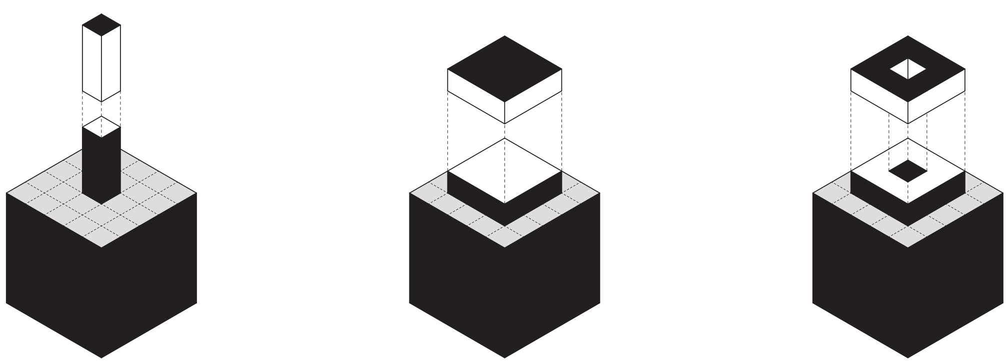
TOWER | *BLOCK* | *COURTYARD*



represents infrastructural and building types that are vertically higher compared to their footprint

represents infrastructural and building types that are horizontally and vertically balanced

represents infrastructural and building types that are arranged around a central (void) space



sectional problem, shifts two categories to the foreground of investigation in this work: context, as the environmental conditions change, and form, as the physical relationship to the ground is a formal question. The proposed types (a) Grounded, (b) Excavated, (c) Underground, (d) Elevated, (e) Raised, (f) Extended, (g) Mobile, (h) Flying, (i) Floating, (j) Submerged, (k) Protected, and (j) Enclosed, describe an object-to-ground relationship formally articulated in response to the changing contextual conditions. The architectural object is investigated through its sectional ability to adapt to its reference surface,

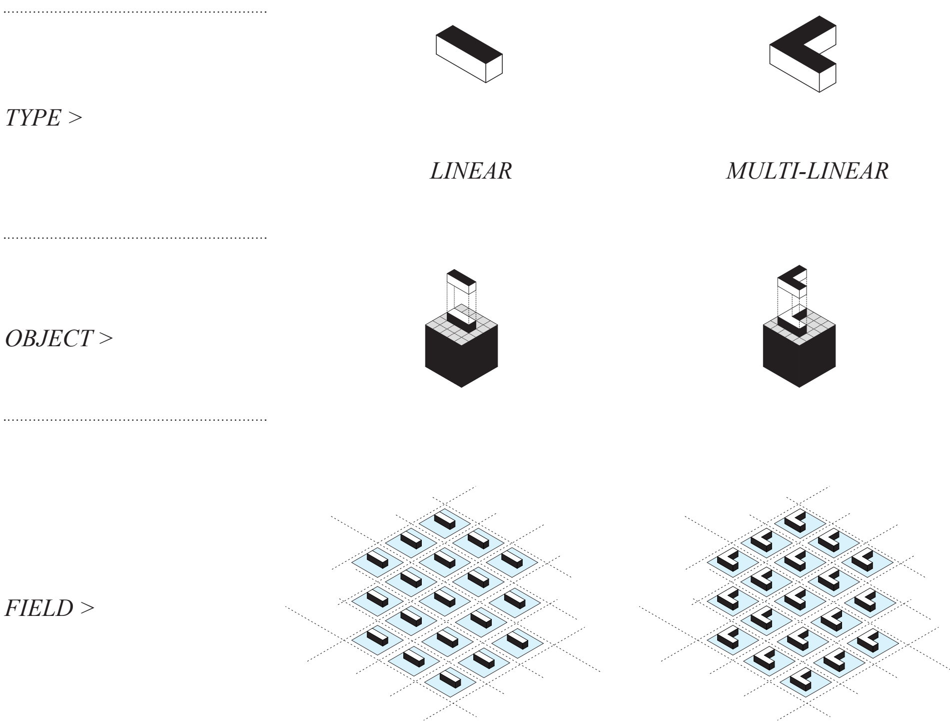


Figure 60. Axonometric drawings of five selected formal types applied to a prototypical urban field.

the ground. The following studies intend to showcase how a selection of five formal types establishes a sectional relationship to the ground based on the twelve object-to-ground typologies proposed in this work. The five formal types, the (a) linear, (b) multi-linear, (c) tower, (d) block, and (e) courtyard, each represent a model of the respective type in a reduced, tectonic, and formal language without any details other than solid mass.

These formal studies have been conducted without assigning a scale but rather focusing on the proportional and geometric qualities of the respective volume.

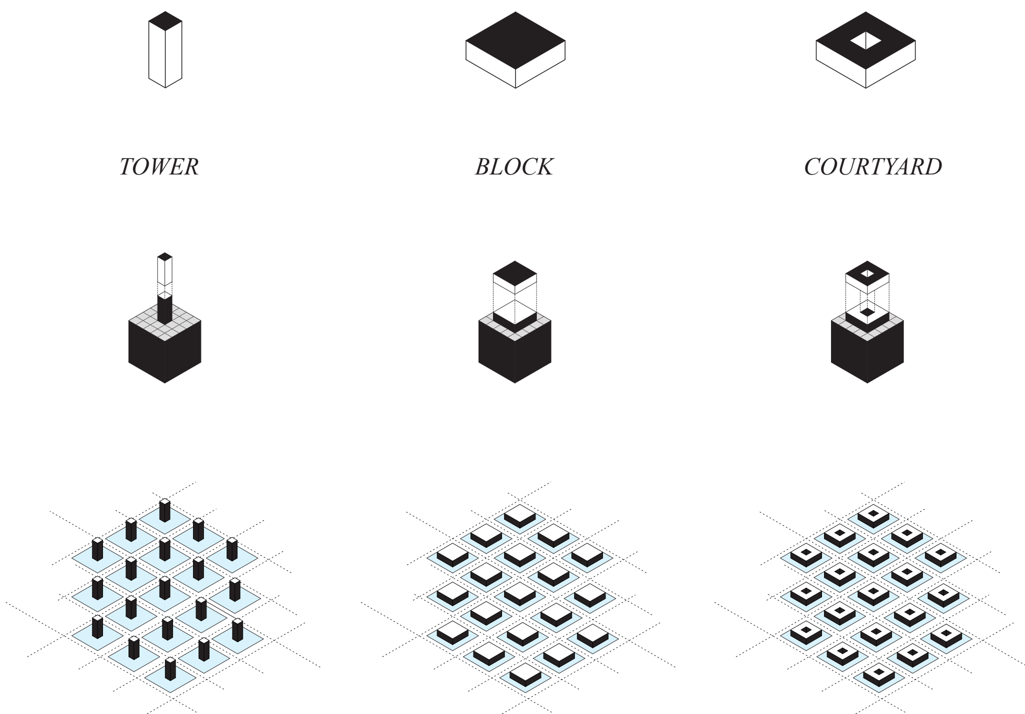
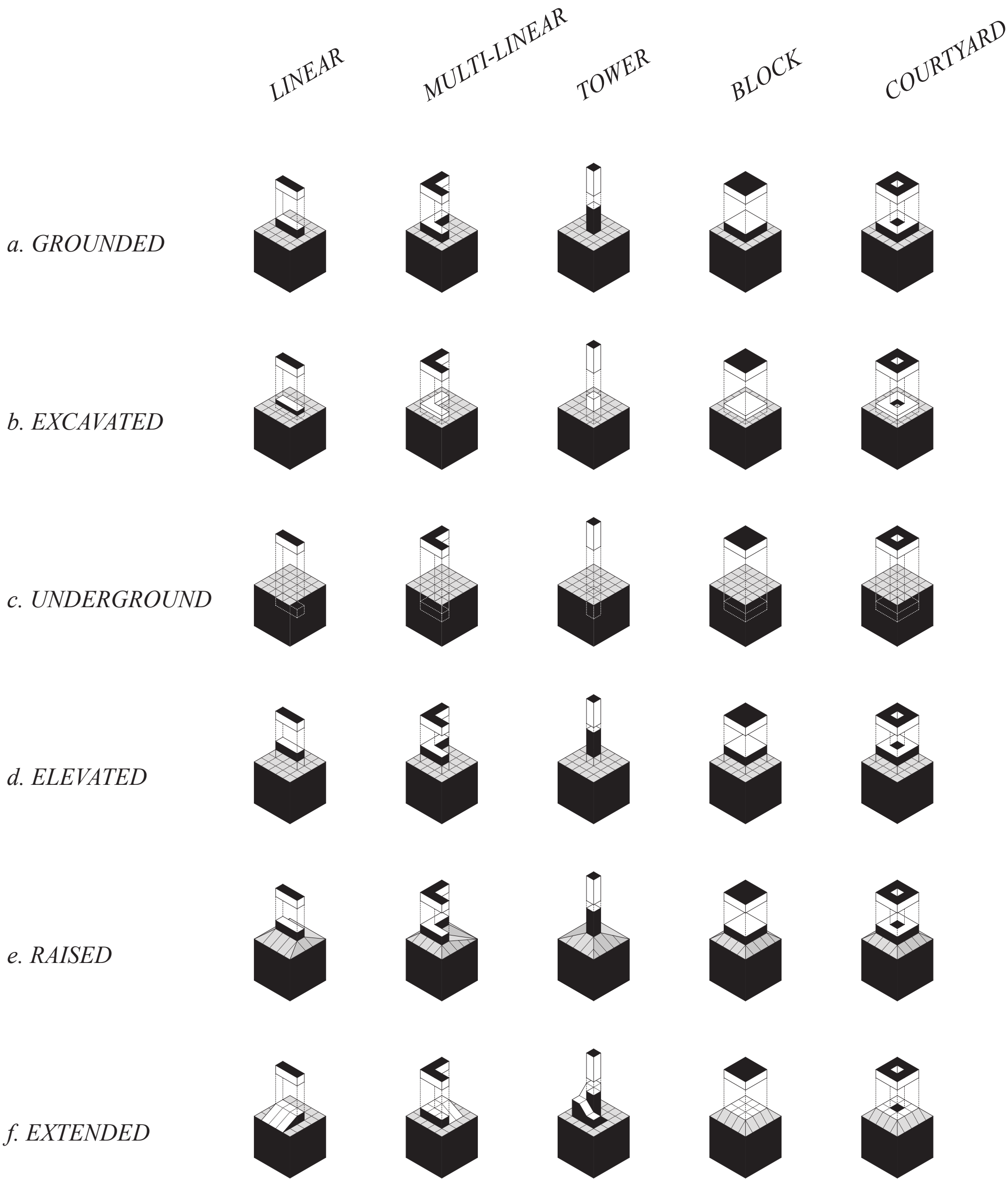
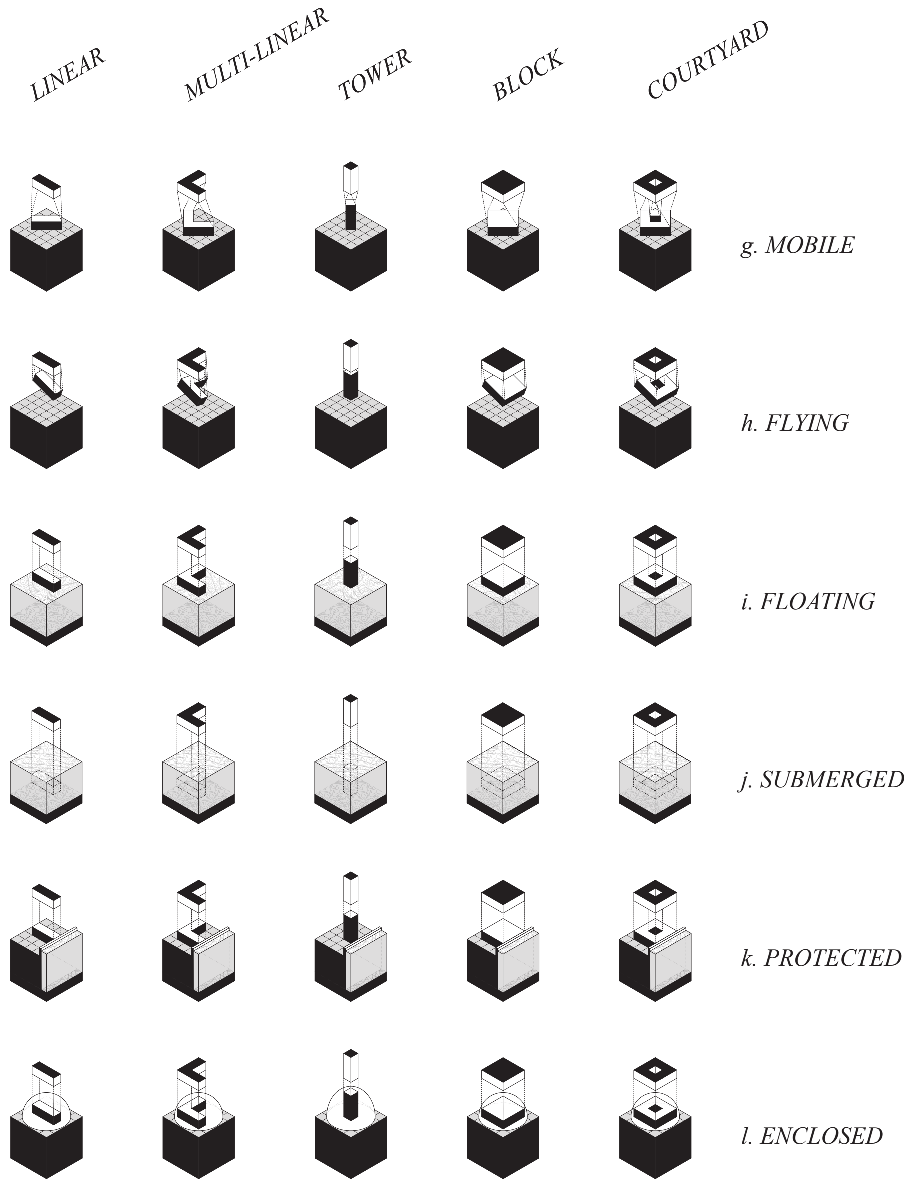
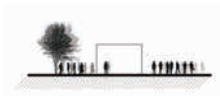


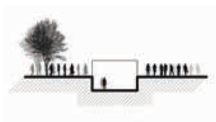
Figure 61. The drawings on pages 190-195 show a prototypical application of the respective formal type utilizing the proposed object-to-ground types.


LINEAR
MULTI-LINEAR
TOWER
BLOCK
COURTYARD
a. GROUNDED
b. EXCAVATED
c. UNDERGROUND
d. ELEVATED
e. RAISED
f. EXTENDED

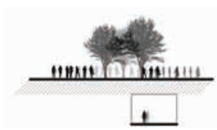

LINEAR
MULTI-LINEAR
TOWER
BLOCK
COURTYARD
g. MOBILE
h. FLYING
i. FLOATING
j. SUBMERGED
k. PROTECTED
l. ENCLOSED



a. GROUNDED



b. EXCAVATED

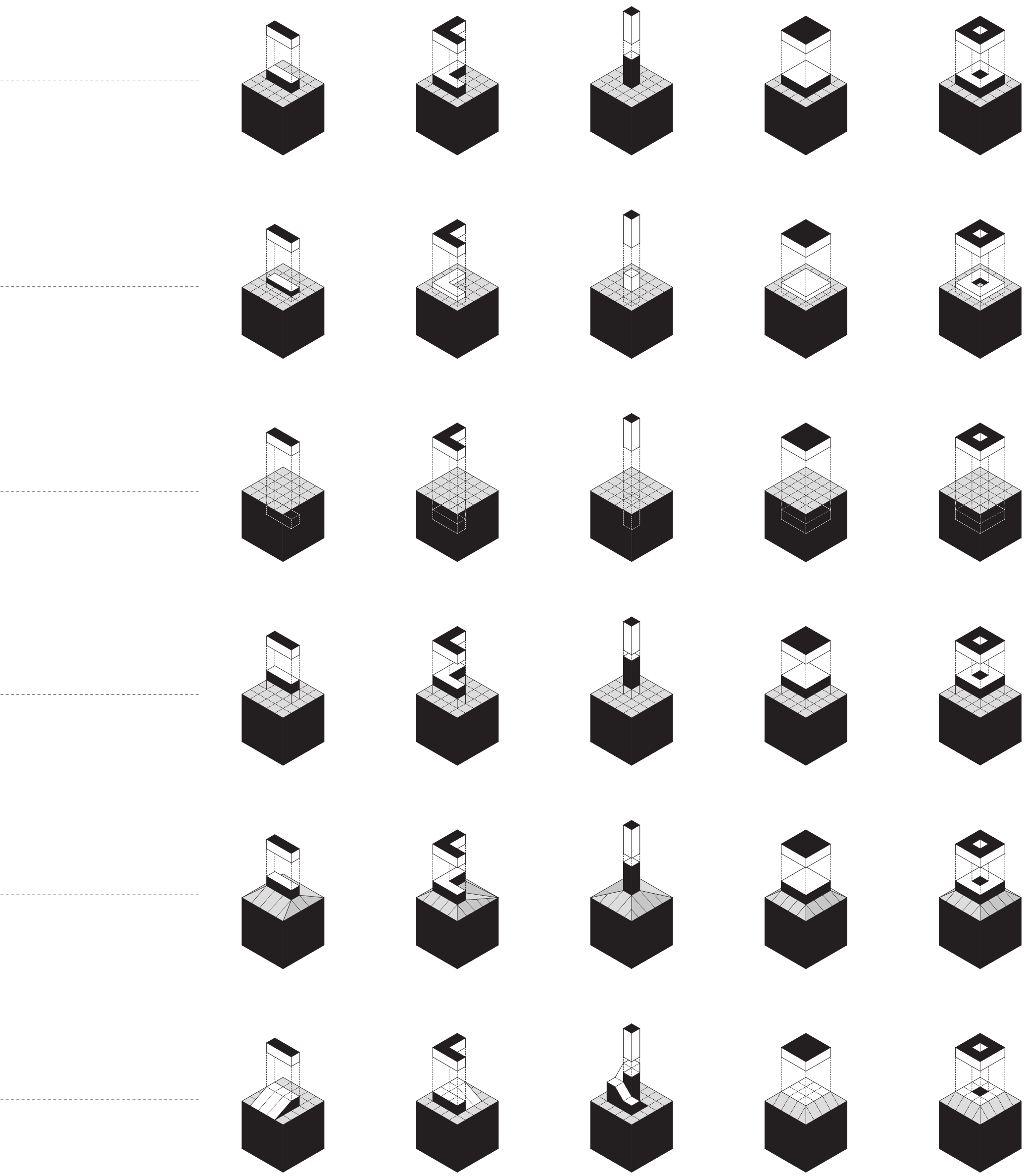


c. UNDERGROUND

d. ELEVATED

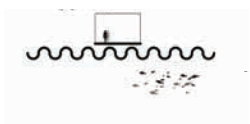
e. RAISED

f. EXTENDED

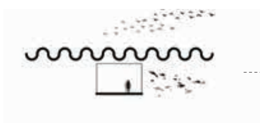


g. MOBILE

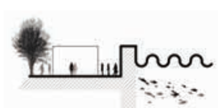
h. FLYING



i. FLOATING

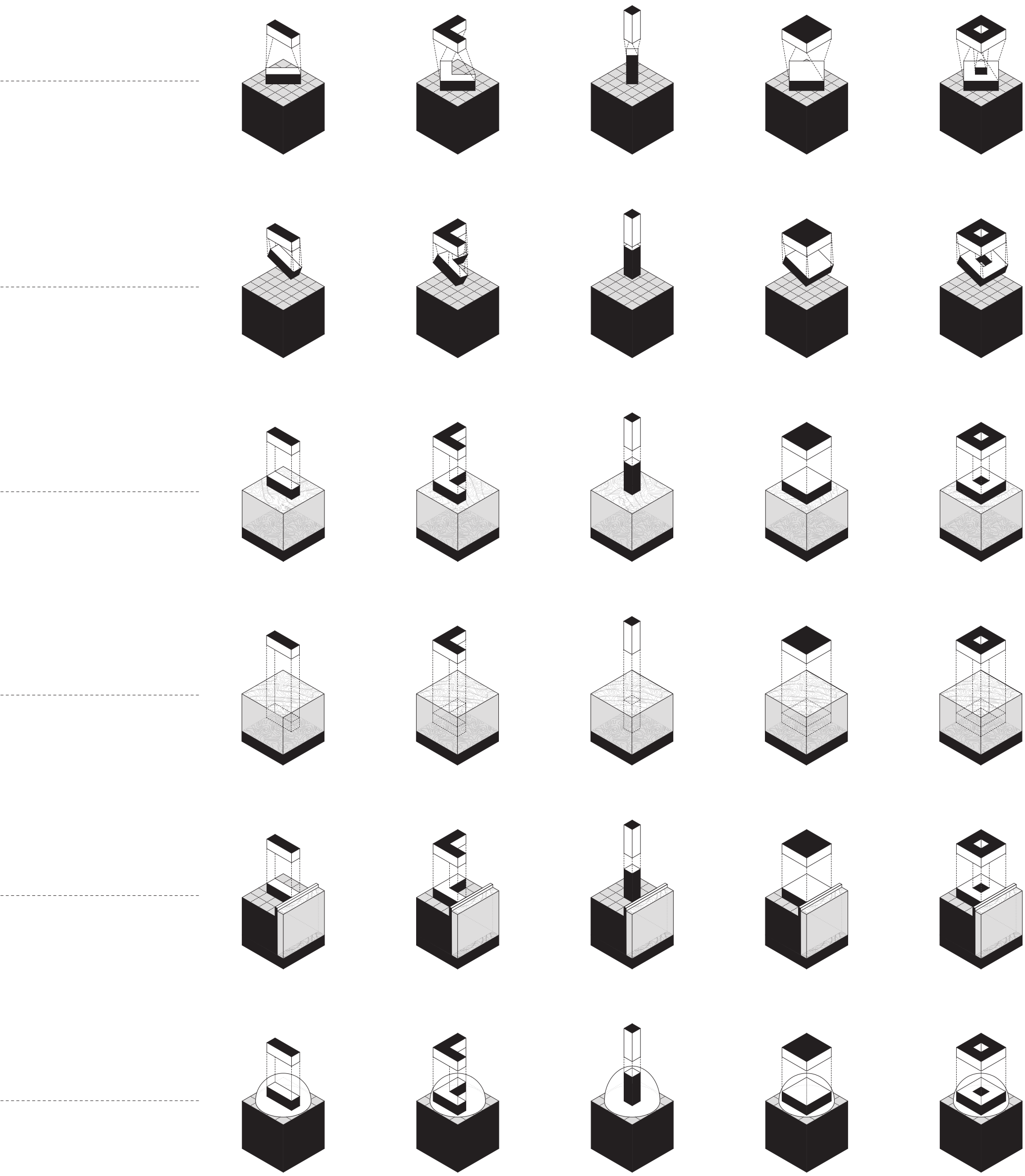


j. SUBMERGED



k. PROTECTED

l. ENCLOSED



Each type addresses the scale of an architectural object, yet, exemplifies urban objects on the infrastructural scale as well, as the proportional qualities remain to be the same regardless of size. The ground condition is shown as "flat" to best resemble the idea of landscape in its most generic, or prototypical, geometric form.
To make a shift from the architectural object to the urban scale, the city can be approached as an assembly of different types arranged on a field. The notion of the urban field has been described by Stan Allen, focusing on the whole over the part, on the collective over the individual.[30]

> *"The term 'field conditions' is at once a reassertion of architecture's contextual assignment and at the same time a proposal to comply with such obligations. Field conditions moves from the one toward the many: from individuals to collectives, from objects to fields."*[31]
>
> *> STAN ALLEN, FROM OBJECT TO FIELD, 1997*

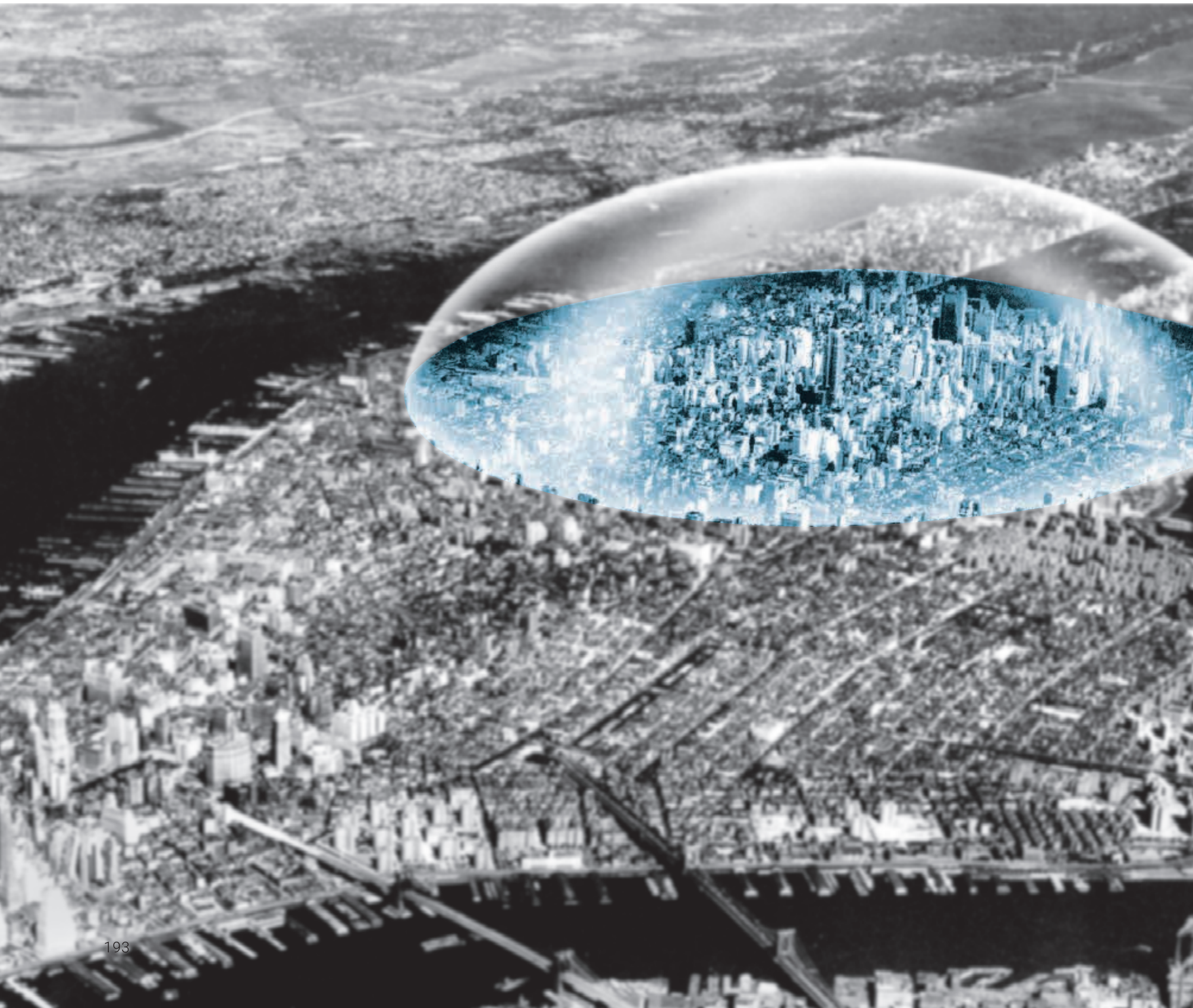
Though the proposed object-to-ground types seem to be applicable to the architectural object scale, their conceptual approach relating the built to the natural environment sectionally is valid and can be applied to the urban field. On the following pages, a series of studies test how the proposed object-to-ground types establish a formal relationship to the ground. The aim is to apply each type to a generic field while forming the described sectional relationship. The object-to-ground typologies can be utilized as a climate adaptation method on the scale of the individual architectural object, the scale of infrastructural elements, or on the scale of the urban field as a collective method for cities. Some of the proposed types are more, others less favoring the object versus the field application.

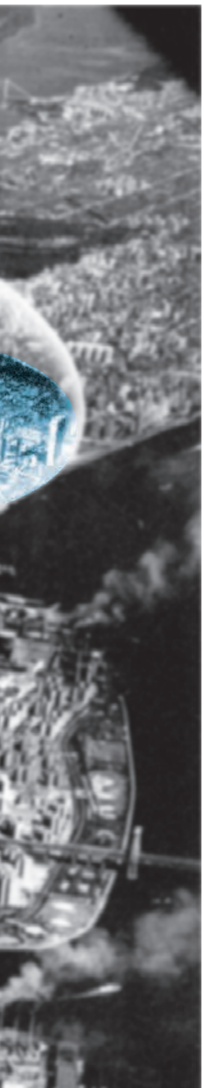
In the United States, the urban fields generated by the subdivision of land

30 Cf. Allen, "Field Conditions."
31 Ibid.

assemble a spatial regime of resource-driven urbanization patterns shaping the landscape. Texas' coastal territories were colonized from the coast inland. These colonization patterns showcase the importance of the coastal city as a typology enabling access to the hinterlands and serving as logistical hubs for trade and commerce. Alongside the westward expansion of US territory, these urbanization patterns have developed a unique type of city, vernacular to the Texas Coast. Within these oil cities of the Texas Gulf Coast, a variety of adaptation strategies have been applied to combat environmental forces and the risks local to the coast. Historically, *"Buildings on Stilts"* can be found along many coastlines and water bodies in the world. These *"Pile Foundations"* resemble the idea of the proposed *"Type d - Elevated,"* the concept of disconnecting the architectural object from the ground has been a common-sense practice for millennia. This object-to-ground relationship allows the building to adapt to conditions of temporary flooding and is a capable solution for almost any topographical condition as well. Buildings with a *"Pier and Beam Foundation"* also fall under the category of *"Type d - Elevated,"* even though the elevation from the ground is relatively small. However, this type also has the ability to respond to flooding, in coastal areas or the hinterlands, to some extent. In addition, the so-called crawl space in between the ground and the building floors, can be seen as a climate-responsive design concept more suitable for warmer zones as the void space enables air circulation and therefore brings a natural cooling effect. Especially in the times of rapid urbanization starting in the 20th century, the *"Slab Foundation"* became the prevalent type constituting an object-to-ground relationship. This approach falls under the most commonly used *"Type a - Grounded"* as described before. Developing strategies for flood hazard mitigation, *"Type e - Raised"* has become a capable hybrid combining a slab foundation on a slightly elevated grade. If *"Site Grading"* is applied to an individual object, water can naturally drain away from the building. However, a raised grade elevation might cause drainage issues in the existing context at lower elevations, imposing additional drainage issues on such areas. The Federal Emergency Management Agency (FEMA) describes a series of options for new constructions and existing buildings in

Figure 62. Buckminster Fuller proposed a geodesic dome over Manhattan to protect the city from environmental impacts. This concept can be seen as a typological approach to climate adaptation the urban scale or even the territorial scale, depending on the diameter of the dome. (Image appropriated from: Archdaily)





flood zones.[32] These guidelines recommend raising the building elevation to protect a building against flood-impacts. Elevation as flood-hazard mitigation ranges from simply lifting the building to an elevation above the flood level, to ground-floor conversion making the lowest level a floodable space.[33] In recent years, *"Floating Buildings"* gained more traction, especially in coastal areas. While houseboats have been a residential typology long before sea-level rise threatened coastal regions, this type is becoming increasingly relevant due to its adaptability to long-term change. After Hurricane Katrina hit the Gulf Coast along the shore of New Orleans in 2005, a series of coastal prototypes were designed and constructed in the city's Lower Ninth Ward. The celebrity-led initiative called *"Make-it Right"* invited architects to come up with innovate concepts after the flood-infrastructure failed during the storm.[34] Morphosis' contribution to this project was the *"Float House"* - an elevated building capable of floating in case of severe flooding. Resembling a hybrid between *"Type d - Elevated"* and *"Type i - Floating"* highlights the opportunity for types to merge. While this approach still focuses on the architectural object scale, large-scale typological adaptations have enabled human settlements since the transition from nomadism to settling down. "*Type k - Protected,*" summarizing levees and dams, sea walls, breakwaters, jetties, and other human-made types that aim to protect cities, focuses on the infrastructural scale of the city. Similarly, Buckminster Fuller's proposal for a three-kilometer Dome over Manhattan in 1960 can be seen as an urban-scale application of *"Type l - Enclosed."*

In an attempt to appropriate evolutionary terms from the life sciences to architecture and the city, three processes of transformation are the most fitting when related to typological studies in the built environment: (1) Mutation of Types - type has the ability to mutate when its elements change, (2) Hybridization of Types - a type has the ability to hybridize when two or more types are combined, and (3) Adaptation of Types - a type has the ability to adapt

32 Cf. FEMA, "Elevating Your House."
33 Cf. FEMA, "Second-Story Conversion – Elevation Project Design Considerations for Hazard Mitigation Assistance Applicants."
34 Cf. Oliver, Thomas, and Thompson, "Resilient and Regenerative Design in New Orleans: The Case of the Make It Right Project."

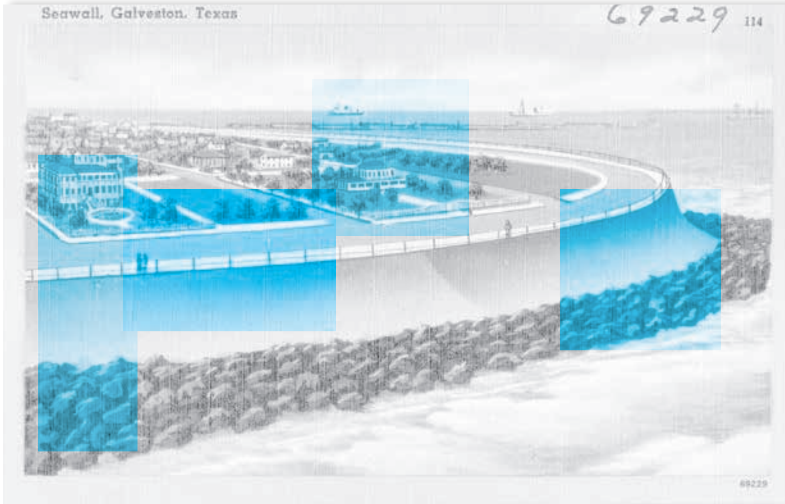
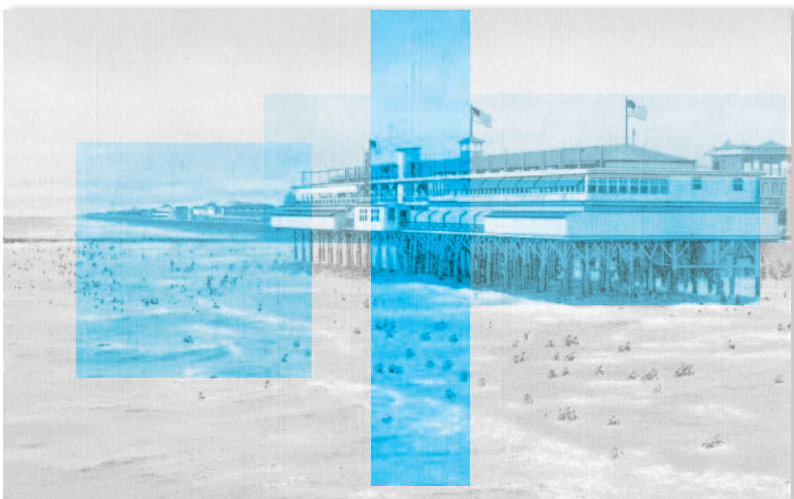


Figure 63. These two postcards of Galveston, Texas from 1930-1945 show two adaptive typologies: a seawall to protect larger urban areas or territories, and a pier elevated on pillars. (Images appropriated from: Digital Commonwealth)



when contextual parameters change. These mutation, hybridization, and adaptation capabilities of types lay the foundation for transforming typologies within the built environment on the territorial, urban, and architectural scale. The type cannot just change itself in response to changing internal factors but also hybridize with other types and, especially, adapt to contextual circumstances. The type is inherently adaptive and by no means a stagnant, unchangeable object isolated from its surroundings. In fact, the type is an integral component of the urban ecosystem and as such capable of responding to change.

Coastal regions are often at the forefront of experiencing climate change impacts, especially flooding and rising sea levels, which represent major threats. Adapting coastal infrastructure is urgent to sustain cities in the changing coastal ecosystem. With changing contextual conditions, the formal response of architecture is primarily concerned with elevation. And while engineering approaches from structural fortification to mechanical inventions help to mitigate and adapt many elements of the urban infrastructure, architects often simply apply such concepts. Concerned with climate change impacts on the city, architects need to (re)define a disciplinary response to environmental adaptation to remain relevant in this pressing discourse. This work presents an initial step to climate adaptation of the built environment within the core of the discipline: the type.

Climate change impacts highlight the duality between the individual object and the collective field. Though similar approaches could be applied to both scales, the question of typological adaptation is ultimately a question of individual versus collective climate change action. As architects and designers, the immediate solution often seems to be the object scale, yet, sustainable climate adaptation requires collective typological adaptation on the territorial, urban, and architectural scale. Looking at successful examples of coastal management, the Netherlands show how adaptation to environmental change is possible as a collective effort over centuries.[35] The Dutch lowlands are protected through a series of coastal engineering types that have been built and adapted over time. However, climate change adds to the vulnerability of that

35 Cf. Pavel Kabat, et.al., "Dutch Coasts in Transition."

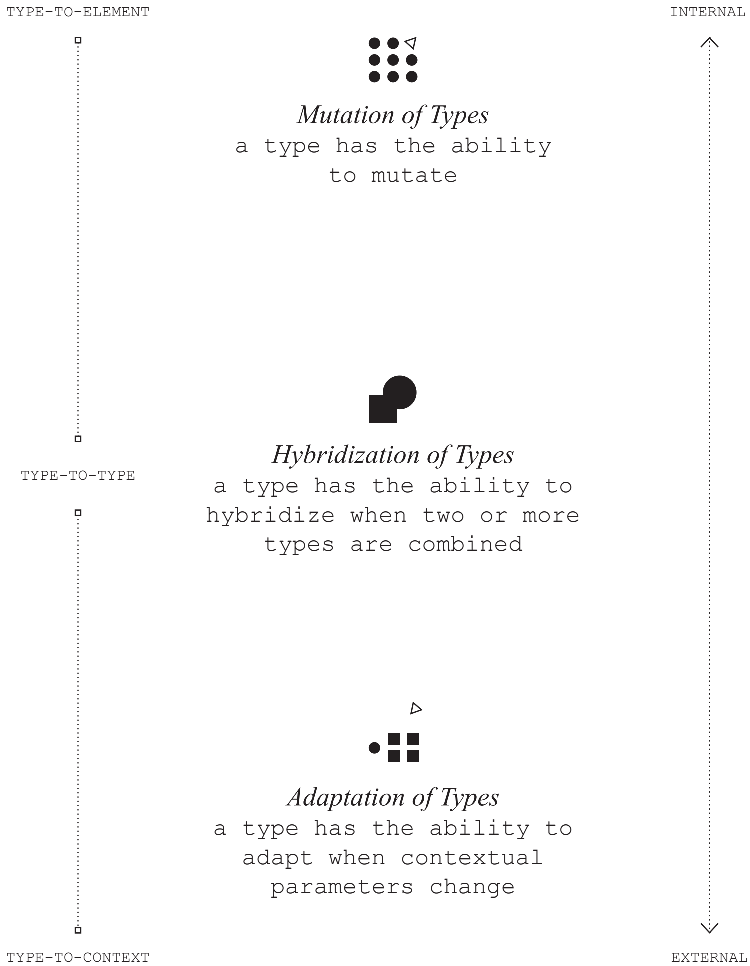


Figure 64. Ability of types to mutate, hybridize, and adapt based on a type-to-element, type-to-type, or type-to-context relationship.

coastal territory.[36] And while a series of typological adaptations have been applied on the architectural and urban scale, the territorial approach might deliver the most efficient, yet unlikely solution: the Northern European Enclosure Dam. This gigantic infrastructural project would reach from Bergen in Norway to Scotland, and from Ploudalmézeau in France to the Lizard Heritage Coast in England.[37] Back to the Texas Gulf Coast, the described coastal barrier for Galveston Bay, called Ike Dyke, is another example of a territorial-scale typological adaptation, protecting several cities.[38] Nonetheless, it is clear that a single intervention will not be able to resolve all climate change impacts and sustain the city in its current state. Rather, a mix of adaptation strategies, from big to small, is necessary to adapt the built environment alongside policy and behavioral changes.

All of these projects, regardless of scale, acknowledge that we live in a Post-Oil Environment, as humankind responds to irrevocable climate change impacts. The adaptation process occurs from the collective to the individual, public to private, territorial to object scale and vice versa. Typological adaptation challenges the architecture of the city at its core: the type.

36 Ibid.

37 See Koch, "The Northern European Enclosure Dam: A Study on the Technical Feasibility of the Enclosure Dam."

38 See Texas A&M University, "Response to USACE Texas Coastal Study."

05

Conclusion

Post-Oil Environments

05

Conclusion

POST-OIL ENVIRONMENTS

We live in a Post-Oil Environment. Anthropogenic carbon emissions created this environment, puncturing the earth's surface to extract, refine, transport, and burn hydrocarbons globally, fueling increasing energy demands. Across the territories of petrochemical production, the flow of oil carves its logistical footprints into the (urban) landscape. The Post-Oil City finds itself in a world that still creates but also experiences a planetary crisis. This crisis destabilizes the ground by shifting the edges between water and land. And while humankind needs to mitigate the causes and drivers of this crisis, it also needs to adapt to irrevocable consequences. This adaptation process requires, in many cases, a different type of architecture and the city, (re)negotiating the relationship to the ground. This work aims to offer solutions on how architecture can develop a disciplinary response to climate change and finds the answer in the discipline's core: the type. Typological Adaptation, as a design approach for architecture and the city, calls for a fundamental (re) assessment of how the urban environment and its elements acknowledge, respond, and plan for changing contextual conditions. It applies the concept of type as a vertical framework to address climate change and its impact on the object-to-ground relationship across scales, delivering a comprehensive method for the initial stages of the design phase in a world where the ground becomes more variable than constant.

As climate change repercussions materialize and the shifting edges of water and land make urban grounds increasingly unstable, (landscape) architects and urban designers need to understand climate change as a vertical problem. The relationship between the built object and the ground is changing as human activity has altered the Earth's atmosphere over the past 200 years and, therefore, the premise of architectural creation: the ground. The many challenges climate change brings to the built environment ultimately involve ground elevation as a crucial parameter. Landscape, as the physical medium that ties the natural and built environment together, sets the stage for 21st century adaptation. As history has shown, large-scale problems demand collective effort to be solved. Architecture as a tool for shaping the physical background of everyday life asks for a complex set of parameters to be addressed at a collective scale. Parameters that directly impact the design of architectural objects, the relationships between these objects, and the relationship between objects and the ground reach from material and immaterial site conditions to cultural impacts embedded into a specific context. Climate change is a complex problem. The solutions are manifold and require collective responses from almost every scientific discipline and profession, and the respective policies to ensure action from the systems scale to individual behavior.

Within the built environment, Typological Adaptation will not solve all climate-related challenges. It is simply an initial approach to adaptation asking: *"what type of city or building responds best to the changing contextual conditions?"* Raising this question is as simple as it is crucial to (1) understand and acknowledge changing conditions, and (2) utilize predictions to design a response. It is an initial question, as *'the type'* fundamentally impacts all its elements over time. While typology as a method creates groups based on any set of parameters, it can also address almost any aspect of architecture within the described categories of context, form, function, materiality, structure, and performance. This work suggests that climate change-related topics need to focus on context above all, yet claims that any built project addresses these five categories eventually. Emerging building technologies to heat and cool buildings more sustainable and low-embodied carbon materials that not only improve the carbon footprint of a building during operation but also during construction and disassembly are some of the most promising approaches to mitigating and responding to selected climate change impacts. Similarly, global sustainability frameworks like the United Nations Sustainable Development Goals provide guidelines for climate change adaptation. They address a variety of environmental challenges and go way beyond what a typological approach could deliver.[1] However, this work focuses on an architecture-specific response that does not claim to address all aspects of climate change but serves as an initial concept to approach the design phase.

Applying the method of type describes the act of thinking in groups based on shared characteristics. As contextual conditions change, the parameters for these groups change too and, therefore, need to adapt. Typological Adaptation is simply a methodological framework to approach the vertical nature of climate change impacts. All proposed types were found in historical precedents and have been built for hundreds of years all over the globe. Therefore, this work does not propose new typologies but outlines the opportunity typology provides conceptually as we mutate, hybridize, and adapt types across scales.

As concluded upon the works of Durand, de Quincy, Moneo, and Rossi, types have the ability to mutate, hybridize, and adapt. Therefore, the contextual framework of typology is a foundational cornerstone of ecological considerations in the early design stages. The proposed typological approach finds a formal response to contextual change by developing groups based on their object-to-ground relationship. Addressing the vertical relationship of climate change to regroup architectural typologies through the lens of object-to-

1 See UN, "The Sustainable Development Goals Report 2022."

ground connections delivers a formal response to this specific facet of environmental challenges.

Following a transscalar investigation, these typologies can be seen as territorial, urban, and architectural adaptation strategies, as the scale of an object or a field of objects could follow this approach. To better understand the historical developments leading up to this stage of planetary crisis, this work outlined the origins of fossil-fuel-based urbanization and identified concrete case studies of petrochemical cities. Looking at the Texas Gulf Coast, this work tied the historical urbanization patterns in this territory to the burning of fossil fuel as a spatial regime that assembles climate change causes, drivers, and impacts in a prototypical way. It shows how this spatial regime generated an urban typology with distinct elements. The Coastal Oil City finds itself at the forefront of contributing to and experiencing the consequences of global warming. This type of city and the types of architectural objects that generate it need to acknowledge the changing contextual conditions, transforming the concept of ground from a reliable constant to a variable over time. As a territory, the Texas Coast, just like many other coastal regions across the world, created new environmental conditions as a premise for its cities, demanding a typological response as to how architecture and the city engage the ground.

On the territorial scale, the PARA[2] adaptation options, including (1) protect, (2) accommodate, (3) retreat, and (4) avoid help to develop initial strategies on a large-scale.[3] After a careful analysis of climate change impacts in the respective region, a mix of those four options could likely help to both mitigate some and adapt to other climate change causes, drivers, and impacts. The typological approach suggests that cities with similar geographic and environmental challenges could be grouped based on shared characteristics. Understanding the issues at stake and comparing them to cities in similar conditions is the first step in grasping the macro-level components of climate change impacts over time. Typological Adaptation on the Territorial Scale asks to address contextual questions first. Focusing on the vertical relation-

2 See Doberstein, Fitzgibbons, and Mitchell, “Protect, Accommodate, Retreat or Avoid (PARA): Canadian Community Options for Flood Disaster Risk Reduction and Flood Resilience.”

3 See WJ. McG. Tegart, G.W. Sheldon, “Climate Change. The IPCC Impacts Assessment.”

ship between object and ground is a first step towards a comprehensive assessment of factors like flood risk, leading to large-scale considerations on suitable elevations for both infrastructural and architectural elements in-between and within cities. Some areas could raise roads, others elevate buildings, and others utilize shoreline protection infrastructures.

On the urban scale, Typological Adaptation applies territorial strategies locally. For existing cities, adaptation of the built environment will often start at the object scale. And while some of the proposed typologies are applicable to the scale of a territory, city, or simply a building, the urban environment as a whole is defined by its individual parts. Therefore, the architectural object will be crucial in achieving (typological) adaptation for the existing urban fabric. The boundaries between scales are blurry as they interdepend on each other. In the planning phases of a project on an urban scale, Typological Adaptation should guide decision-makers toward solutions that address the variable nature of future ground conditions. In navigating the complex dynamics of urban planning, Typological Adaptation emerges as a pivotal approach, implementing territorial strategies at the local level and advocating for the adaptation of the built environment. While the proposed typologies resonate across various scales, from territories to cities to individual buildings, it is crucial to recognize that the city's adaptive capacity not only lies in its infrastructure but also in its constituent architectural elements. Therefore, the interdependence between them highlights the need for Typological Adaptation across scales, leading to solutions capable of addressing ground conditions as a variable.

On the architectural scale, the focus shifts from the many to the one, from collective to individual, from the field to the object, and vice versa.[4] The individual object can start the climate adaptation process bottom-up, impacting the larger-scale of the urban fabric. Bypassing the constraints imposed by various factors such as long-term governmental policies and legislation, as well as considerations related to ownership and financial matters, the architectural object remains a dynamic entity with the potential to adapt to its surrounding environment faster. This adaptability extends to the object-

4 Cf. Allen, “Field Conditions."

to-ground relationship, wherein the building's physical interaction with the ground will no longer be static but responsive to the ever-changing contextual conditions.

> *Typological Adaptation is, in essence, a dynamic approach, allowing architectural objects to serve as resilient entities capable of accommodating the shifting grounds that form the new basis for contextual design.*

Climate change requires architecture and the city to adapt to shifting environmental conditions faster than ever before. And while environmental impacts have shaped the design of human settlements for millennia, the connection between contextual conditions and formal design responses seems now often lost. Almost any region of the world produced an environmentally driven set of vernacular typologies on the scale of both architecture and the city – at least at some point in time. Yet, in the spirit of the Industrial Revolution, mass production and capitalist interests, among many factors on the social systems scale, shifted the focus away from buildings as integral parts of the urban ecosystem. Instead of responsive architecture supporting the urban fabric as a dynamic system, the architectural object became a repetitive element unrelated to its surroundings.

In the emerging 20th century, when anthropogenic climate change slowly started to unfold in the background, environmental design strategies took different paths. The members of the International Style aimed to create a globally exportable building concept. The building as an object that could fit any condition utilizing the technological progress, mass production techniques, and logistical networks.[5] For Le Corbusier, Neutra, Breuer, Johnson and many others, building the idea of an international architecture did not focus on environmental topics but rather on the concept of architecture as a socially responsible product. Richard Buckminster Fuller also promoted the

5 Cf. Jordy, "The International Style in the 1930s."

architectural object as a mass-produced product, yet his approach was more environmentally aware. Known as the *'Dymaxion Houses,'*[6] he proposed a series of shelters that united architecture, transportation, and climate control in one integrated concept.[7] Fuller's domes, applicable to the scale of both architecture and the city, were significant contributions to the discourse of *'Future Cities,'* highlighting the relationship between industrialization, structural design, and environmental topics.[8] Interested in ecology and environmental protection, Fuller's proposal for a geodesic dome over Manhattan in 1959, is a perfect example of a typological approach to environmental adaptation.[9] Covering the city in a three-kilometer-diameter dome is an urban-scale example of typological adaptation.

In response to climate change impacts, FEMA has outlined adaptation options for both new constructions and existing structures in their general guidelines for building in the flood-zone.[10] As flood-zones are increasing, the new reality of changing ground conditions trickles through, from macro-level policies, to micro-level design guidelines. In 2016, the Department of Housing and Urban Development granted 48 million Dollars to the relocation of the citizens of Isle De Jean Charles, Louisiana. The people living on the island, situated on the Gulf Coast in the Mississippi Delta, are the first *'Climate Refugees'* of the United States.[11] It is the first of probably many resettlement undertakings to come along the shores. Rising sea-levels will impact smaller cities, towns and dwellings the most, as these communities often lack the economic power to protect themselves through infrastructural mega-projects. Climate adaptation of the built environment is essential to prevent the retreat from coastal territories. Without acknowledging the problem, developing strategies, and adapting to change, many coastal cities will struggle.

Without a doubt, the climate crisis is an environmental and humanitarian

6 See Ananthasuresh, "Buckminster Fuller and His Fabulous Designs."
7 See Aus dem Moore et al., Post-Oil City. The History of the City's Future. p. 15
8 Cf. Díaz, "Dome Culture in the Twenty-First Century."
9 See McCormack and Phillips-Hungerford, "A Dangerous Precedent; the Geodesic Dome as a Credible Space Architecture Typology."
10 See FEMA, "Elevating Your House."
11 See Crepelle, "The United States First Climate Relocation: Recognition, Relocation, and Indigenous Rights at the Isle de Jean Charles."

crisis, impacting the global ecosystem and all its members. Environmental adaption is a collective challenge. As oil-production has once again become a major geopolitical tool of power in times of a Pandemic and War in the emerging 2020s, the days of petrochemicals seem far from being over. This becomes visible in the coastal oil cities of the Texas Coast. Typological Adaptation of architecture and the city is one of many strategies for tackling climate change impacts, by asking what type of architectural object performs best in response to the changing contextual conditions. The undeniable reality of climate change makes adaptation of architecture and the city more pressing than ever. As the consequences of climate change manifest in increasingly tangible ways and the very ground we build upon becomes less stable, it is clear that traditional approaches to design are no longer sufficient. The vertical dimension of climate change, particularly its impact on the relationship between built structures and the ground, emerges as a critical consideration for architects and urban planners.

In the Epoch of the Anthropocene, the impact of human activity on the climate, is visible. The Texas Coast and its petrochemical industry have generated a new landscape: a landscape of oil and water that contributed to the Post-Oil Environment we live in, requiring a typological response.

> *"Post-Oil Environments acknowledge the changing environmental conditions as a direct result of burning fossil fuels. They describe the current transition period away from carbon dependency towards a collective ecological awareness of anthropogenic climate change."* [12,13,14]

12 Jenewein, "The Texas Coast as Geopolitical Territory: The Spatial Regime of Burning Fossil Fuels in Coastal Landscapes of Oil."

13 Jenewein, "The Frequency of (in-)Dependence: A Post-Oil Future in a Post-Pandemic World. Case-Study Texas Coast in the Time of COVID-19."

14 Jenewein, "Post-Oil Environments."

Typological Adaptation offers a methodological framework for understanding and responding to this vertical dimension of climate change. By grouping architectural typologies based on shared characteristics and reevaluating their object-to-ground relationship in light of changing environmental conditions, this approach lays the groundwork for resilient and contextually responsive design solutions. At its core, Typological Adaptation acknowledges the dynamic nature of environmental challenges and calls for a shift towards place-related, ecological design principles. By considering the interplay between contextual conditions and formal design responses across territorial, urban, and architectural scales, Typological Adaptation offers a pathway towards adaptive, sustainable futures for our built environments. However, the application of Typological Adaptation and its implementation faces challenges such as socio-economic constraints, technological limitations, uncertain long-term effectiveness, and political and regulatory obstacles. Acknowledging these limitations is crucial for maximizing the effectiveness and sustainability of Typological Adaptation. This work calls for revisiting the concept of typology in architecture for challenges such as fundamental as climate change.

As we confront the reality of the Anthropocene and the profound impact of human activity on our planet, the urgency of this work cannot be overstated. In the words of Charles Darwin, "adapt or die." It is time for architects, urban designers, policymakers, and communities to heed this call and embrace Typological Adaptation as a crucial tool in our collective efforts to navigate the challenges of a rapidly changing climate and increasingly unstable grounds.

In this Post-Oil Environment, the shift of the ground condition from constant to variable requires a typological response, challenging the very type of architecture and city. Typology, as a categorization-method, helps to inform the initial design and planning phases as a concept to (re) connect the natural and the built responding to change.

Figure 65. Wind Turbines in Corpus Christi, Texas.

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Figures

FIGURES

All figures are "by author" unless marked differently.
The sources for figures containing data can be found in the bibliography.

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We live in a Post-Oil Environment. Anthropogenic carbon emissions created this environment, puncturing the earth's surface to extract, refine, transport, and burn fossil fuels across the global logistics landscape. Based on a transscalar investigation, this work describes how this process evolved into a spatial regime, focusing on the vertical impacts of climate change as the shifting edges of water and land challenge the very premise for architecture and the city: the ground. It outlines strategies on how architecture can develop a disciplinary response to climate change adaptation and finds the answer in the discipline's core: the type. Based on the theories of typology by Durand, de Quincy, Rossi, and Moneo, this work proposes twelve typologies found in historical precedent, characterized by their distinct object-to-ground relationship. These typologies adapt to contextual conditions and are applicable to various scales - from the architectural object across the urban to the territorial scale. Typological Adaptation presents a method for architects and urban designers during the initial design and planning phases in a world where the ground becomes increasingly more variable than constant and, therefore, requires a typological response.

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