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Y02A as Praxis: An innovation Model for Coastal Resilience and Adaptation

by Richard Lloyd Hindle

Thesis submitted in fulfilment of the requirements for
the degree of

Doctor of Philosophy

under the supervision of

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University of Technology Sydney
Faculty of Design, Architecture, and Building



Abstract

This thesis argues that the patent system and patented technologies have a distinct agency in coastal systems and can be operationalized to advance adaptation and resilience efforts. It brings together discourse on coastal resilience and adaptation, the sociotechnical aspect of environmental innovation, histories of the patent system and legal theory, and case studies that reveal the agency of patents in large-scale complex environmental systems. It offers recommendations for strategic integration of patented technologies and the global patent system into the contemporary coastal resilience and adaptation toolkit. The research presented foregrounds the role of inventors, institutions, policy, funding, private research & development, and environmental planning practices operating within coastal zones. It highlights the contributions of these diverse actors to an expanded repertoire of coastal adaptation and resilience technologies. Central to the thesis is the theorization of an innovation model, posited in the conclusion, in which patents, and the patent system, help build adaptive capacities and resilience in coastal systems through integration of spatial planning and design praxis with the Y02A patent classification scheme. The Y02A classification scheme was created (c.2018) to track technologies for adaptation to climate change, including a broad range of technologies related to coastal process and development. Tracking innovation in this emergent sector through the Y02A classification scheme builds adaptive capacity and anticipatory frameworks for the management of sequential innovation in adaptation and resilience sectors, presenting the allied disciplines of environmental design, planning, and engineering, with the opportunity to integrate datasets and novel technologies into praxis, therefore spatializing innovation through real-world projects.

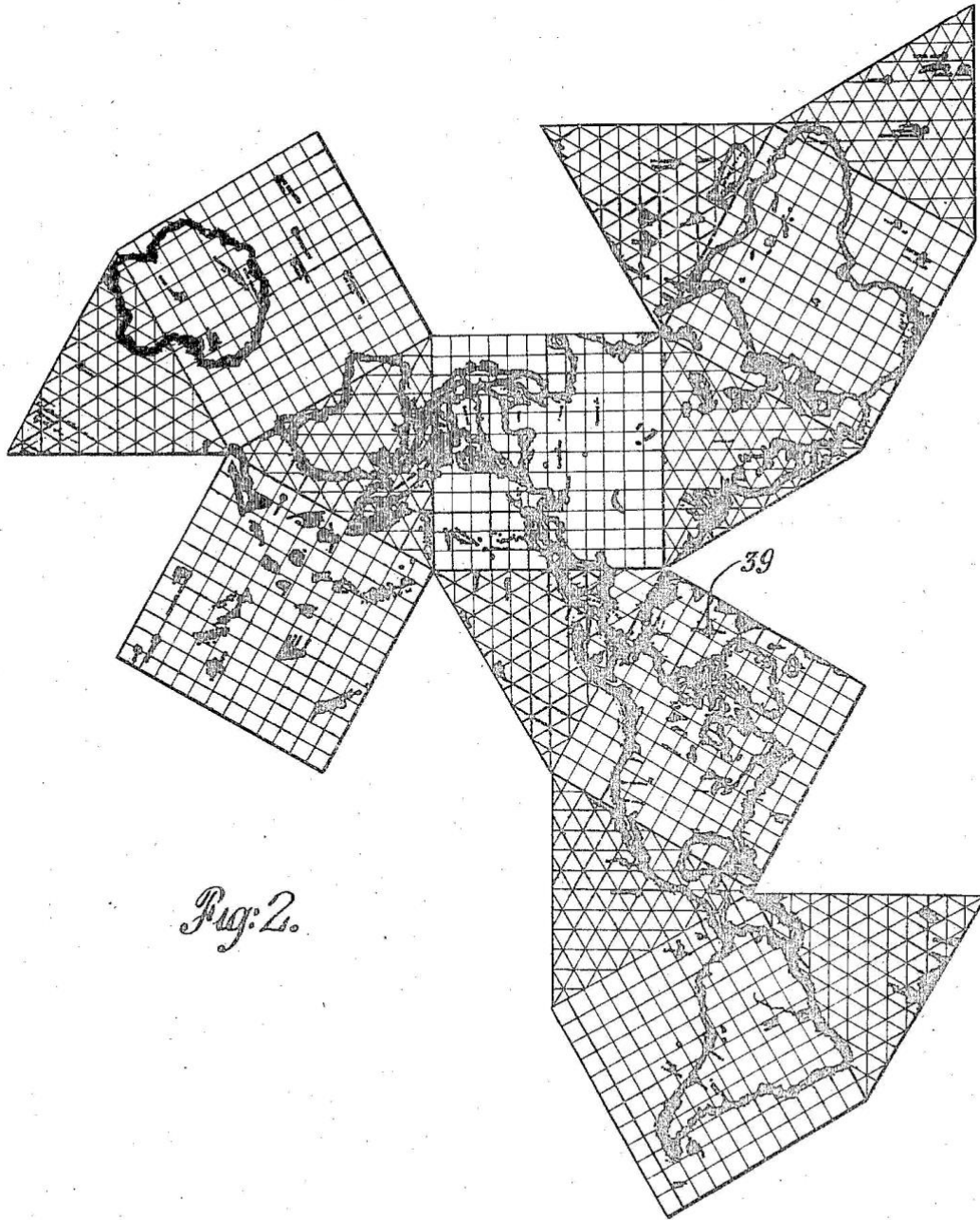


Fig. 2.

INVENTOR
 RICHARD BUCKMINSTER FULLER
 BY
Donald W. Robertson
 ATTORNEY

Patent US2393676 for "Cartography" Granted to Richard Buckminster Fuller in 1944. The Coordinate system, popularly known as the Dymaxion map, shows the landmasses as islands in a vast ocean.

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Preface: Professional Background and Interest

In many regards this dissertation represents the culmination of my research on environmental innovation revised and refined to address the challenges of coastal adaptation and resilience. As a professor of Landscape Architecture and Environmental Planning at the University of California Berkeley, I have developed a substantive record of research, teaching, and public engagement that explores the role of the patent system, and patented technology, in the built environment across scales and geographies – advocating for an expanded canon of technological precedents and strategies with the design and planning disciplines. Development of this thesis project was undertaken, in collaboration with my advisors Charles Rice (UTS) and Elizabeth Mossop (UTS), with the ambition of translating my established historical and practice-based research into a forward-looking strategy that addresses the complex social, technical, and environmental, process that converge in coastal zones. It represents my best approximation of how the patent system, and novel technologies, integrated with environmental design and planning praxis may address the global challenges facing coastal communities and ecosystems through an expanded field of technological innovation that occurs across environmental sectors.

My research interest in the subject of patents emerged slowly through an inductive research process that began approximately 16 years ago (c. 2007) as a designer/consultant writing technical specifications and guidelines for a novel vegetated building systems under development by the architect Ateliers Jean Nouvel. Having exhausted the all books, peer-reviewed science, and professional journals, and other familiar sources in the Liberty Hyde Bailey Library at Cornell University, I clicked on the newly created *“Include Patent References”* button on the web-of-science search page to see what this novel search category might reveal. To my surprise a long list of patents was returned by the search engine, chronicling a history of innovation that was previously unknown to me and not documented in scholarly literature on the subject.

Among the documents I downloaded through subsequent searches was the first known patent for a green wall, titled the *“Vegetation Bearing Architectonic Structure and System,”* invented by Stanley Hart White, Landscape Architect, Professor, and grandfather of modern

design theory.¹ It took me a few years, and many research tangents, to realize the layered meaning of Professor White's invention and why it remained entirely unknown in the design community. Today I can confidently say that Professor White, and his prescient green wall system, not only provided a window into the origins of vertical gardens as a technical field, but also revealed the inherent societal value of a patent system that archives, cites, makes public, and otherwise manages sequential innovation. The timing and context of my re-discovery also chronicles a 60-year lag between the initial invention and eventual implementation of the green wall in contemporary cities, thus pointing to the considerable distances that exist between domains of technological knowhow in emergent sectors and the allied disciplines of environmental design and planning. For how could the evolution of core technologies remain such a mystery to the fields from in which they were developed?

Since these early days of discovery my research has evolved into a broader inquiry of patent history, law, technological innovation, and the environment – including original research on the Mississippi River, California Delta, San Pablo Baylands, and the history of patent law as originated in Venice Italy six centuries ago.² Unifying these works is the often overlooked, yet latent, relationship of patented technology to known place and geographies – what I now refer to as 'geographies of innovation.' Researching these geographies requires the establishment of linkages between patents, patent law, and the environment, weaving a path through layers of government, policy, economics, and broader innovation studies. From these fragments a picture emerges, often revealing nuanced stories and curious details of how environmental transformation and technological innovation are intertwined, and mediated, to create more complex assemblages. Obviously, my role as professor of Landscape Architecture and Environmental Planning also provides important professional and intellectual context. Having worked professionally on large-scale urban and coastal sites helps ground my research in the

¹ Richard L Hindle, "A Vertical Garden: Origins of the Vegetation-Bearing Architectonic Structure and System (1938)," *Studies in the History of Gardens & Designed Landscapes* 32, no. 2 (2012): 99–110.

² Richard L Hindle, "Inventing Venice: An Urban and Environmental Innovation Model from the Lagoon City," *J. Pat. & Trademark Off. Soc'y* 100 (2018): 529; Richard Hindle, "Levees That Might Have Been," *Places Journal*, 2015, <https://placesjournal.org/article/levees-that-might-have-been/>; Richard L Hindle, "Patent Scenarios for the Mississippi River," *Journal of Architectural Education* 71, no. 2 (2017): 280–85; Richard Hindle, "Prototyping the Mississippi Delta: Patents, Alternative Futures, and the Design of Complex Environmental Systems," *Journal of Landscape Architecture* 12, no. 02 (n.d.): 32–47, <https://doi.org/10.1080/18626033.2017.1361084>.

pragmatics of site construction and theoretical horizons of design and planning, helping to inform my research and provide a framework through which to approach this dissertation.

Over the past decade of research, a recurrent theme has emerged through the interrelations between technological innovation, patents, and coastal systems. At first, evidence of the coevolution of technological and coastal systems revealed itself slowly, primarily through detailed research projects and design speculations that built an inductive understanding of the subject area through iterative study and laid the groundwork for development of this dissertation. Establishment of the Y02A classification scheme in 2018, and rollout through 2020, hastened my pace of discovery and galvanized interest in the future technology in the coastal adaptation and resilience sectors. The Y02A initiative provides a deductive, policy driven, framework for my research and provides a distinct opportunity to for governments, planners, designers, and scientists to align innovation and the patent system with the practices and research discoveries that will define the future of coastal systems.

Integration of new site technology into the built environment is among the fundamental practices of the allied professions of environmental design and planning (i.e. landscape architecture, urban design, architecture, regional planning, etc.). Central Park, in New York City, serves as a well-known example of this process as the design by Landscape Architect Frederick Law Olmsted and Calvert Vaux integrated a novel subsurface tile drainage system that was previously untested in a public landscape. The drainage system was developed in England and made possible by the invention of a patented tile fabrication machine before it was tested in agricultural plots in upstate New York and later integrated in the parks infrastructure by sanitary engineer George Waring (c.1856-1857). Today, environmental design and planning disciplines are again chartered to advance urban infrastructure as the professions address the global issues of climate change and sea level rise for which no “instruction manual” or “textbook” exists as a guide – a paradigm that necessitates open ended, flexible, and sociotechnical approaches to the future of technology and the built environment.

As environmental systems and the designed urban landscape become more technologically advanced, performance driven, structurally complex, networked, ecologically hybrid, novel, and integrated, a cohesive strategy is required for the allied disciplines of

environmental design and planning to engage the processes of innovation. Patents and the patent system offer one such mechanism through which to comprehend technological change and will play an increasingly important role in the emergent environmental innovation problem space through the management of sequential innovation, development of knowledge infrastructure, projection of future imaginaries, and transfer of technology in this sector. Importantly, these processes may also be operationalized through design and planning praxis to help build a more sustainable, adaptive, and equitable, environment. Many questions remain regarding the invention, prototyping, testing, and implement the environmental technologies of the future, however the work is imperative. This thesis takes the first tentative steps towards integrating environmental innovation, coordinated by the Y02A, into environmental design and planning praxis, raising issues of disciplinary concern through the lens of coastal adaptation and resilience.

Introduction

The parallel genealogy of patented technology and coastal systems spans six centuries and can be observed today in the morphology of anthropogenic coasts around the world. Historically this resulted from the origins of patent law in 15th century Venice where the sociotechnical legal framework of the Venetian Patent Statute of 1474 facilitated urbanization of the *Leguna Venata* through advanced dredge, drainage, and ground stabilization technology, associated with public works in the Venetian territory.³ More recently the European Patent Office launched the Y02A patent classification scheme (circa.2018/20) to facilitate the diffusion, transfer, and implementation of “Technologies for Adaptation to Climate Change,” covering the cross-sectoral innovations in coastal and riverine technology, including flood control, mapping, sensing, human health, infrastructure, etc. The nearly three-quarter million (723,254) patents currently tagged in the Y02A classification chronicle the ongoing parallel evolution of technology, urban, and coastal systems in the context of global climate adaptation and resilience efforts. Given these convergent factors, might the patent system be operationalized to facilitate coastal resilience and adaptation efforts and help build the next layer of coastal infrastructure?

Of course, coastal infrastructure in the contemporary context of resilience and adaptation theory, and praxis, is no longer the fixed heavy dikes, breakwaters, and revetments, of yesteryear. Global adaptation and resilience strategies will require diverse technologies ranging from soft nature based systems, to distributed micro-grids, urban storm water systems, social-networks, artificial marine habitats, mapping software, remote sensing, coral reef restoration, robotics, and yet unforetold inventions that will reformat social, ecological, and technological interactions in coastal regions.⁴ This shift in technology is being instigated by a changing environment and also cultural changes in our relationship to water and the ocean.

³ Hindle, Richard “Inventing Venice: An Urban and Environmental Innovation Model from the Lagoon City.” *Journal of the Patent Office Society*

⁴ Jeremy M Hills, Evanthe Michalena, and Konstantinos J Chalvatzis, “Innovative Technology in the Pacific: Building Resilience for Vulnerable Communities,” *Technological Forecasting and Social Change* 129 (2018): 16–26; Lynette H L Loke et al., “Complexity for Artificial Substrates (CASU): Software for Creating and Visualising Habitat Complexity,” *PloS One* 9, no. 2 (2014): e87990–e87990; Jana Koerth et al., “A Typology of Household-Level Adaptation to Coastal Flooding and Its Spatio-Temporal Patterns,” *Springerplus* 3, no. 1 (2014): 1–10; Richard JT Klein et al., “Technological Options for Adaptation to Climate Change in Coastal Zones,” *Journal of Coastal Research*, 2001, 531–43.

Coastlines are no longer conceived of as thin boundary lines between terrestrial and marine systems, instead they are now understood as an interconnected set of anthropogenic and environmental processes operating within an expanded coastal zone. As contemporary landscape theoreticians such as Anuradha Mathur and Dilip da Cunha point out, the ‘terrain’ of water extends through, and blurs, geographical boundaries and is deeply intertwined with culture and ecology.⁵ Scientist grappling with similar challenges of classification and definition have developed definitions for coastal systems shaped by humans, referring to these complex assemblages as ‘coastal anthromes’ in which humans are agents of biospheric and geomorphic change, through patterns of settlement, infrastructure, agriculture, technology, and management practices, leading to a widened conception of the coastal zone and human agency within coastal systems.⁶ Adaptation and resilience efforts within this expanded coastal zone must embrace the complexity of human agency in coastal systems and develop new tools and technologies through which to address the challenge – collectively representing the scale, scope and opportunities withing this expanded field.

Redefinition of coastal systems is happening concurrent to unprecedented global warming and climate change. The need for an expanded toolkit for coastal adaptation and resilience is therefore timely as climate change and environmental risk radically reconfigure social-ecological-technical systems (SETS) in coastal regions. SETS are ecosystems “defined by the flow and accumulation of energy through the medium of organisms, constructed infrastructure, institutions, and their environment” in which human intention and values have agency and can drive ecological processes alongside non-anthropogenic forces.⁷ Catastrophic events such as hurricanes, floods, drought, ecological degradations, subsidence, etc., are catalyzing change in these systems, impacting human and environmental systems alike and leading to irreversible changes in coastal ecosystems. Given the scale and scope of the challenges across these coastal anthromes, questions arise as to the most effective way to advance adaptation and resilience efforts. As decades of research affirms, policy, land use planning, nature-based solutions, and

⁵ A. Mathur, D. da Cunha, and University of Pennsylvania. School of Design, *Design in the Terrain of Water*. Applied Research + Design Publishing, 2014)

⁶ Eli D Lazarus, “Toward a Global Classification of Coastal Anthromes,” *Land* 6, no. 1 (2017): 13.

⁷ Ariel E Lugo, “Effects of Extreme Disturbance Events: From Ecesis to Social–Ecological–Technological Systems,” *Ecosystems* 23, no. 8 (2020): 1726–47.

social infrastructure, will all play a foundational role in building adaptive capacity and resilience in the coastal zone – effectively addressing the social and ecological elements of the system.⁸ However, many questions remain concerning the role of technology in coastal social-ecological-technical systems and how best to coordinate efforts to enact change.

Dynamic environmental and cultural forces are at work in coastal systems, leading to novel assemblages in which risk and climate change are major determinants of innovation. Recent studies show risk and natural disaster catalyze innovation and are integral to recovery and response efforts.⁹ The correlation of natural disaster and innovation is an unfortunate reality, but it does indicate a future trend as catastrophic events multiply and innovation is required. It is projected that innovation in the risk mitigation and adaptation sectors will expand rapidly as climate change impacts humanity and environmental risk increases.¹⁰ Emerging from this literature is a sense that technology will be integral to adaptation strategies and that patented technologies will parallel this evolution. The mechanisms through which these new technologies are invented, disseminated, tested, and operationalized promise to expand the agency and scope of resilience and adaptation frameworks by engaging the sociotechnical aspects of coastal systems.

Policy is one mechanism for change that will help calibrate innovation in response to climate change and risk. As the Porter Hypothesis states, environmental regulation and policy may in fact drive innovation and profitability.¹¹ This is evident across pollution causing industries first researched by Michael Porter, as well as in “green” technologies such as renewable energy such as solar that policy catalyzes innovation.¹² As coastal regions continue to be impacted by

⁸ W Neil Adger et al., “Social-Ecological Resilience to Coastal Disasters,” *Science* 309, no. 5737 (2005): 1036–39; Hakna Ferro-Azcona et al., “Adaptive Capacity and Social-Ecological Resilience of Coastal Areas: A Systematic Review,” *Ocean & Coastal Management* 173 (2019): 36–51; Min Kim et al., “Sustainable Land-Use Planning to Improve the Coastal Resilience of the Social-Ecological Landscape,” *Sustainability* 9, no. 7 (2017): 1086; Michael Greg Lloyd, Deborah Peel, and Robert W Duck, “Towards a Social–Ecological Resilience Framework for Coastal Planning,” *Land Use Policy* 30, no. 1 (2013): 925–33; Firas Saleh and Michael P Weinstein, “The Role of Nature-Based Infrastructure (NBI) in Coastal Resiliency Planning: A Literature Review,” *Journal of Environmental Management* 183 (2016): 1088–98.

⁹ Hongxiu Li, “Innovation as Adaptation to Natural Disasters,” 2017.

¹⁰ Qing Miao and David Popp, “Necessity as the Mother of Invention: Innovative Responses to Natural Disasters,” *Journal of Environmental Economics and Management* 68, no. 2 (2014): 280–95.

¹¹ Stefan Ambec and Philippe Barla, “A Theoretical Foundation of the Porter Hypothesis,” *Economics Letters* 75, no. 3 (2002): 355–60.

¹² Kyunam Kim and Yeonbae Kim, “Role of Policy in Innovation and International Trade of Renewable Energy Technology: Empirical Study of Solar PV and Wind Power Technology,” *Renewable and Sustainable Energy Reviews* 44 (2015): 717–27.

climate change and new policies and plans are implemented, technology will parallel this process. The origins and evolution of these new coastal technologies are fascinating to ponder as the scale and scope of coastal adaptation and resilience and truly global endeavors.

Patented technology, and the patent system, provide one lens through which to comprehend and analyze the ever-evolving relationship between technology and coastal systems. Innovation in coastal technologies can be traced historically through the global patent archive since dedicated patent classifications have been organizing innovation in this sector for centuries. Extant records of patent documents maintained in archives of the United States Patent and Trademark Office (USPTO), or European Patent Office (EPO) provide a high-fidelity window into the technological innovations that have, or had the potential to, shape coastal systems. In the most recent iteration, the Y02A scheme reformulates this relationship through a strategic focus on climate adaptation. It builds upon long-established classification systems, namely the Cooperative Patent Classification (CPC) and the International Patent Classification (IPC), which have been used globally to categorize technology and track innovation - including coastal technologies organized by the E02B subclass for “Hydraulic Engineering” covering “Man-made devices for using or controlling natural bodies of water.”¹³ Distinguishing the Y02A is cross-sectoral focus on the core technologies of green infrastructure, human health, water, mapping, environmental restoration, and other technologies related to coastal adaptation and resilience.

The relative newness of the Y02A classification scheme, and general obscurity of the patent system within the discourses of coastal adaptation and resilience, create a unique situation. On one hand, the existence of a global framework for the management and diffusion of innovation in coastal sectors is a provocation, or call-to-action, with the possibility to facilitate positive change in communities and ecosystems. On the other, the mechanisms and processes through which novel adaptation and resilience technologies are invented, tested, and implemented through environmental/spatial design, planning, and engineering praxis remain largely unknown and untried – leaving gaps in knowledge that may slow the pace of innovation.

¹³ “CPC Definition - E02B HYDRAULIC ENGINEERING (Ship-Lifting E02C; Dredging E02F),” accessed February 8, 2021, <https://www.uspto.gov/web/patents/classification/cpc/html/defE02B.html>.

Situated at this juncture, the thesis explores the complexities innovation in this emergent space through detailed analysis of specific cases related to the anticipated scope of coastal adaptation and resilience, highlighting the diverse actors and new networks engaged in the process, and looking towards the future for pathways to operationalize of the Y02A by integrating patent data, innovation studies, and novel technologies, into planning and design praxis.

Outline

The thesis builds an argument for strategic integration of the patent system, and patented technologies, into the praxis of coastal adaptation and resilience planning through theoretical framing, development of six case study chapters that analyze relevant issues, and a conclusion that theorizes working methods for integration of patent data and novel technologies into coastal planning and design praxis. The body of the thesis contains six case study chapters covering the specifics of existing patent/environment entanglements and the opportunities presented by more coordinated approaches. In conclusion the case studies and theoretical framing are synthesized through articulation of an innovation model exploring the unique role of spatial design and planning disciplines in the testing and implementation of climate adaptation technologies.

The six case study chapters proceed as follows. The first three chapters, *Observations and Natural Case Studies, chapters 1-3*, reflect on the current situation in this innovation space, revealing a sometimes messy, incongruent, and largely unknown process of innovation that parallels development of coastal technologies. Through analysis of pilot projects, government policies, business ventures, and other examples, a narrative is developed to elucidate the idiosyncrasies of how new technologies in the coastal sector are developed and issues associated with the inventive process. This includes detailed studies on the invention of coastal infrastructure integrated with oyster habitat, the ongoing search for novel coastal stabilization technology, and the role of corporate interests in the development of artificial reef technology. Each addresses a range of interconnected issues that emerge from coastal innovation that may be raised as part of design praxis, and in the implementation of the Y02A classification scheme, for the adaptation of coastal systems. Since the Y02A is nascent in the longer arch of patent history, many of the precedents and references drawn upon necessarily predate the existence of the classification scheme. This fact does not diminish its potentiality, in fact they help rationalize the need for such framework to exist.

The final three chapters, *Opportunities and Emerging Frameworks, chapters 4-6*, look at the opportunities and potential of integrating the patent system (i.e. Y02A, data, forecasting,

infrastructure, law) and innovative patented technologies into environmental design and planning praxis. This includes a survey of new coastal infrastructure paradigms emerging through patented technologies, examples of the successful integration of patent innovation studies into adaptation and resilience planning projects, and a detailed analysis of the Y02A patent classification scheme as a framework for innovation in coastal adaptation and resilience efforts. Collectively the chapters reveal the role of patented technologies, and the patent systems, in coastal innovation, pointing towards establishment of an innovation model that coordinates these efforts through strategic integration of the Y02A scheme in praxis.

Observations and Natural Case Studies (Chapters 1-3)

The first case study (Chapter 1) titled *“Inventing Oyster-tecture: Dimensions of an Innovation Chasm in Coastal Adaptation and Resilience Technologies”* focuses on technological innovation, and development of intellectual property, during coastal resilience design and planning competition programs. Over the past decade the number of design and planning competitions focused on coastal adaptation and resilience has increased as governments and private entities seek solutions to the challenges of climate change. This process has been very successful in highlighting a range of design and planning strategies; however, analysis of the mechanisms through which novel technologies are developed and tested reveals an idiosyncratic process of technological innovation that calls into question how novel technologies are invented, tested, and implemented in the context of coastal adaptation and resilience planning. This chapter analyzes the invention of ‘oyster-tecture’ systems through the competition process and contrasts it with development of similar technologies developed by inventors outside of the design and planning process.

Oyster-tecture is a compound word (oyster + architecture) coined in 2010 by Kate Orff (SCAPE Landscape Architects) as part of Rising Tides exhibition at the Museum of Modern Art in New York, USA. It refers to the intentional integration of oyster habitat with coastal defense structures designed to mitigate storm surge, stabilize ground, clean waterways, and improve ecological health. The novel planning strategy, and the core technology of oyster-tecture was a breakthrough in planning disciplines – reaching a wide audience and leading to prototype

development. Irrespective of the popularity and reach, the process of invention leading to development of core technologies is idiosyncratic to planning and design competition processes. The invention of oyster-terrace is further complicated by the existence of prior-art and pilot projects in the 1990's that reveal an alternate point of origin and lineage of technological innovation. Two disparate points of invention, and their respective timelines, reveal a disjuncture between the initial invention of core technologies for oyster-terrace, uptake of the idea in design disciplines, and adoption of these technologies in the contemporary coastal adaptation and resilience sector. From the perspective of innovation studies, this lag represents a unique 'chasm' in the adoption cycle of a new technology. Dimensions of this chasm reveal idiosyncrasies of the innovation process in the design, planning, and coastal resilience planning sectors and a perceived distance between these processes and other established innovation networks. Evidence of a chasm is developed in this chapter through comparison of the inventive process for oyster-terrace to conventional models for the diffusion of innovation, and an analytical narrative timeline that explores the technical, social, and institutional context. Is it possible that integration of innovation studies in planning practice, and the establishment of the YO2A, might help close the chasm?

The second case study (chapter 2) titled "*A wild goose chase? The search for alternative coastal stabilization technologies and the emergence of new actor-networks*" explores the iterative and ongoing quest for systems to mitigate erosion and movement of dynamic coastal edges. Coastal stabilization is a global phenomenon that has paralleled the development of ports, cities, shipping routes, and infrastructure, for millennia. Today, coastal stabilization is again a global issue gaining relevancy through hastened coastal development, sea level rise, increased storm frequency, and other climate change induced threats to coastal communities and ecosystems. The limits of existing technologies such as seawalls, breakwaters, jetties, and groins, necessitates a search for 'alternative' technologies that are cost effective, ecologically beneficial, materially efficient, buildable, innovative, and otherwise address the changes occurring in coastal systems. As the word 'alternative' implies many of these systems are being developed outside, or adjacent to, conventional process for development of coastal infrastructure typically undertaken by government agencies, contractors, and interagency

funding sources, thus challenging these established networks through novel pathways for innovation.

Alternative coastal stabilization technologies often emerge through alternative pathways for innovation, involving entrepreneurial innovation, private research and development, patented technologies, competitive grants and awards, and an array of collaborative ventures across private and public sectors. This case study analyzes the various pathways through which alternative coastal stabilization technologies are realized, overlaying the theoretical framework of Actor Network Theory, to highlighting and contextualize the diverse range of inventors, corporations, communities, and institutions, in the implementation of coastal works. Five “alternative” technologies, and their associated networks, are analyzed to gain insights about an innovate process that impacts coastal systems and attempts to instigate changes in process within institutions such as the United States Army Corps of Engineers (USACE). Specific cases included the advent of the “Wave Robber” by Webster Pierce, the “Reaction Breakwater” by Lewis M. Haupt, the “Holmberg System” by Dick Holmberg, Beach Cones deployed in southern Louisiana, and Seascope Artificial Seaweeds pilot project in Cape Hatteras, North Carolina. Each example explores the nuances of the search for alternative coastal stabilization systems and the networks and actors involved in the process, with the aim of identifying mechanisms through which innovative solutions to coastal stabilization are realized. As a case study for coastal adaptation and resilience efforts, it illustrates how patents, and the patent system, engage broad constituencies in a process of change while confronting entrenched power structures.

The third case study (chapter 3) titled *“Corporate Ecologies: the pitfalls and promises of industrialized artificial reef technology”* investigates the interrelation between the patent system and establishment of the artificial reef sectors in Japan and the United States. Artificial reefs have been created in oceans, seas, lakes, and rivers around the world for centuries with the ambition of increasing fish yields, altering species distribution, and altering the ecology of the ocean at grand scales. In general, artificial reefs refer to human-made structures installed in aquatic habitats that serve as a substrate and/or shelter for organisms such as fish, mollusks, and crustaceans. Corporate research and development play an important role in the realization of artificial reefs, linking industry to large-scale environmental processes and the ecological

engineering of marine systems. Origins of artificial reef programs in Japan and the U.S. were linked to national policy and funding programs, but also to the patent system which was used to catalyze investment in the newly established sectors. Analysis of this process reveals the role of private industry, policy, and the patent system, in the creation of artificial reefs and brings perspective to this global industrial and ecological entanglement that continues through a dedicated patent class for artificial reefs included in the Y02A patent classification scheme.

Countries around the world, including the United States, Japan, Australia, and others throughout Europe, South America, and Asia have coordinated artificial reef programs to improve marine fisheries – with thousands of hectares and millions of individual reef units currently in operation. Artificial reefs also have a distinct patent class in the Cooperative Patent Classification (CPC) system with a long history of innovation chronicled in patent documents, revealing a complex relationship between private business, technological innovation, and environmental transformation. The policies, funding, and core technologies that constitute these partnerships are important to consider as we approach environmental and ecological engineering challenges in the context of coastal adaptation and resilience efforts as they offer a window into the pitfalls, and promises, of engineering marine ecosystems through corporate investment and strategic partnerships. It also provides an important reference for analogous environmental engineering works that will be developed as nations adapt to climate change and large-scale environmental degradation that no single government entity is equipped to address.

Opportunities and Emerging Frameworks (Chapters 4-6)

The potentiality of integrating the patent system, and patented technologies, into coastal adaptation and resilience planning is far reaching, providing opportunities to expand the toolkit through the adaptive capacities of technological innovation. The final three chapters (4-6) address these issues and opportunities. The fourth case study (chapter 4) titled *“Knowledge Infrastructure for Coastal Infrastructure – utilization of patent innovation searches in the Bay Area Resilience By Design Challenge”* introduces the section, offering an alternate epistemology to chapter 1, *“Inventing Oyster-tecture: Dimensions of an Innovation Chasm in Coastal Adaptation and Resilience Technologies,”* through an analysis of coastal adaptation and

resilience planning integrated with prior-art searches and patent innovation research utilizing the knowledge infrastructure of the patent system. The global patent archive is among the world's largest technological database and a robust form of knowledge infrastructure with potential to inform contemporary coastal adaptation and resilience efforts. Patent documents have been archived for six centuries globally and provide a valuable dossier of technological knowledge in every sector of the known Technosphere, including environmental technology. Although the primary function of the patent system is bureaucratic management of innovation and establishment of legal rights for inventors, it also serves as a repository of technical knowledge, providing deep insights about innovation, past discoveries, imaginaries, and future trends. This vast archive may be interpreted, translated, and be used as sources in legal, technical, and non-technical domains alike – including the emerging sectors of coastal adaptation and resilience.

Translation between of technical knowledge in the global patent archive and the development of strategies for coastal adaptation and resilience provides specific opportunities to build on sequential innovation and integrate sociotechnical processes into site design. Detailed analysis of the “Grand Bayway” project developed by the Common Ground Team during the 2017 Resilience by Design Bay Area Challenge provides insights about this process. The Team used patent innovation studies, coupled with a design and envisioning process, to develop innovative strategies for adaptation of the subsided Baylands site. The case offers specifics of how patent innovation studies, patent data, and specific technologies can be integrated into design and planning praxis to inform regional strategies for coastal adaptation and resilience. The Common Ground's team approach as unique among the nine international multidisciplinary teams as it leveraged patent data and knowledge infrastructure to help problems solve.

The fifth case study (chapter 5) title *“New infrastructure paradigms for coastal adaptation and resilience”* explores how new forms of coastal infrastructure relate to new forms of technology chronicled by the Y02A and global patent system. The language and theories of coastal adaptation and resilience have evolved to necessitate novel forms of infrastructure and technology that address the complexity of socio-ecological relationships in coastal zones. This chapter explores the emerging role of patented technologies in decentralized, hybrid, smart,

local, and small infrastructure that address issues of adaptation and resilience in coastal systems. These new infrastructure paradigms are highly entrepreneurial, innovative, and nimble, utilizing technologies such as micro-grids, robotics, artificial intelligence, and small-scale distributed systems, to build and prototype critical infrastructure in culturally and environmentally diverse regions – making them highly relevant to strategies for coastal adaptation and resilience. As these new paradigms are innovation driven and may coalesce quickly, they can address a range of emergent coastal issues and bypass entrenched and slower pathways for infrastructure delivery.

A shift away from large-scale and centralized approaches to critical coastal infrastructure reveals alternate pathways for infrastructure delivery and novel technologies developed to address this expanding scope. Innovation is vital within this sector and patented technologies are sometimes developed through prototyping, research, and pilot projects that address a range of coastal issues. This case study explores the evolution of these new infrastructural paradigms and their application in coastal resilience and adaptation, highlighting the inventors, agencies, and role of patents in emergent sectors of coastal infrastructure. The need for an expanded toolkit is timely as climate change and environmental risk reconfigure social-ecological-technical systems (SETs) in coastal regions through catastrophic events such as hurricanes, tsunamis, floods from extreme weather, etc. Infrastructure that supports new social-ecological-technical relationships in coastal region will take diverse forms built through the development of new technologies and through shifting perspectives on coastal infrastructure.

The sixth case study (chapter 6) titled *“The Y02A Patent Scheme as Anticipatory Framework for Coastal Adaptation and Resilience Planning”* explores the adaptive capacity of technology as it contributes to anticipatory governance and planning for probable, plausible, pluralistic, and performative futures. The Y02A patent classification scheme was created by the European Patent Office in April 2018, and rolled out globally through 2020, to organize climate adaptation technologies, including those related to coastal systems, flood control, adaptation of existing infrastructure, human health, and technologies for mapping and sensing the environment.

The Y02A scheme is highly relevant to Coastal planning and design activities as it tags and organizes innovation in a range of coastal and riverine technologies and provides cross-sectoral insight into technological trends - functioning as an anticipatory framework for governance in these emergent sectors. As a mechanism for the management of technological innovation the Y02A scheme also builds adaptive capacity within the coastal adaptation and resilience space through the diffusion of technological information, increased searchability, focused patent classes specifically addressing climate adaptation in coastal, riverine, and urban systems. The Y02A patent scheme has the capacity to help governments, policy makers, planners, and designers prepare for an uncertain future. Analysis of the Y02A scheme's organizational structure and origins in the policy initiatives of the Paris Agreement and Kyoto Protocol are explored in relation to coastal adaptation and resilience efforts. Since no "textbook" or "instruction manual" exist for the adaptation of coastal systems in the face of climate change, the living repository of technology coordinated by the Y02A has the capacity to link the adaptive capacity of technology to site and urban systems through the allied disciplines of environmental design and planning.

Notes for a Conclusion

In the concluding chapter the thesis addresses issues of operationalization and implementation of Y02A technologies through the articulation of an innovation model that addressing the issues and opportunities revealed in the six case studies. As such, the conclusion offers a summary of the findings and offers a recommendation for how the Y02A can be integrated with design and planning practice and operationalized to chart coastal futures. This is theorized to involved the integration of Y02A patent data and metrics into planning and design knowledge infrastructure so it may inform development and management of coastal systems at geographical scales, building innovative coastal systems through pilot projects, testing, and implementation of novel Y02A technologies, and development of core technologies from within the fields of environmental design and planning to establish technological frontiers and core technologies in adaptation and resilience sectors.

Methodology

Source material for this project is built from a deep reading of patents and environment. Born in the epoch of the Anthropocene, it is premised on the idea that innovation does not only happen inside a factory, or from Silicon Valley startups, it extends into complex and large-scale environmental systems more networked, hybrid, and degraded than ever before in history. Thus, it seeks novel ways to leverage the process of innovation for positive environmental and societal outcomes. Given the intersectional nature of the topic, I have developed unique research methods that are now integrated into this thesis. In summary the research methods involve two distinct yet highly interconnected processes. In the first, a range of textual, image, and classification searches yield primary patent document that are then correlated with environmental systems, known geographies, and inventors, to build a composite understanding of the actors engaged in this unique type of environmental work. In the second, parallel deep readings of environmental history and theory are collated with patent law and the history of global patent infrastructure. These seemingly disparate primary research processes yield a range of source material that bring together science and technology studies, theories of spatial planning and design, urban history, obscure patents, contemporary design projects, and stories of inventors from around the world, collectively operating within a broader and protracted coastal adaptation resilience space. Together these research processes provide a range of materials that aggregate to a much larger picture of the sociotechnical processes that shape our environment through innovation.

Patent documents and data used in this thesis are compiled using publicly accessible search engines including those offered by the European Patent Office (EPO) Espacenet search engine (<https://worldwide.espacenet.com/>), United States Patent and Trademark Office (USPTO) website (<https://www.uspto.gov/>), and Alphabet Companies, Google Patent Search (<https://patents.google.com/>). At times I have also employed the use of propriety patent search services such as Wisdomain Actionable Patents (<https://www.actionablepatents.com>) to manage the bulk data and analyze text, however these proved too costly and cumbersome to maintain as they work best with contemporary searches in well-established sectors of technology such as medicine and telecommunications. Publicly accessible patent searches

provide all users with powerful tools for discovery, yet often specialized research requires some prior knowledge of the patent system's unique organizational structure. In this context the Y02A is particularly important, as it creates a user-friendly organizational structure for climate adaptation technologies, helping to speed up discovery. In development of this thesis patent searches were conducted using the Y02A scheme and more traditional keyword, citation, and classification searches within the CPC, IPC, and USPC.

Patent searches yield a wealth of primary documents, metadata, bibliographic information, and timelines, that I use to reconstruct environmental histories and narratives regarding the relationship between technology and the environment. Much of the original work associated with this research process involves correlating patent documents and data with specific geographies, pilot projects, and built works. The outcomes of this initial net-casting phase are usually unknown, as it requires time consuming surveys of environmental history, policy, theory, and law, that often lead into new subject areas that challenge my assumptions and expand the scope of my work. Most of the source material gathered during this process includes government reports, contracts, case law, corporate history, local news media, policy papers, peer-reviewed literature, and other esoteric or arcane sources. For example, my interest in the subject of artificial reefs led me first through the history of reef technology and science to the establishment of an entirely new patent class. Along the way it necessitated I learn aspects of Japanese patent law, read congressional hearings, and inform myself on national policy, to make connections between policy, technology, and the advent of artificial marine ecologies. Having evolved from my prior work in this area, this type of research brings together the sociotechnical aspect of environmental innovation, histories of the patent system and legal theory, and case studies that reveal the agency of patents in large-scale complex environmental systems. In this process I have sought ways that designers, planners, and governments can utilize these precedents and mechanisms to improve the environment and society.

Concurrent to the penning of the dissertation the European Patent Office serendipitously implemented the Y02A classification scheme (circa 2018-2020), covering the cross-sectoral technologies of climate adaptation and mitigation. This timely example of convergent evolution provides an important institutional framework for my established ongoing research, helping to

situate this dissertation within global initiatives for technological innovation in the coastal adaptation and resilience sectors. Establishment of the Y02A patent classification scheme follows from broad policy directives originating with the Paris Agreement and Kyoto Protocol with the goal of building adaptive capacities through technological innovation. These initiatives cut a clear transect through coastal adaptation and resilience sectors and are interwoven with this thesis as appropriate.

Arrival of the Y02A during the formative stages of the thesis simultaneously bolstered, and complicated, the research process. Existence of a global policy driven initiative to focus the patent system on adaptation technologies creates an important touchstone for the thesis, and a new way to search and interpret innovation. For example, entirely new classes of technology were created as part of the Y02A, making it easier to find and reference new technologies in previously non-existent sectors. For example, Y02A30/60 – “Planning or developing urban green infrastructure” establishes a new classification scheme for urban infrastructure by reorganizing existing related patents and creates a system to organize future innovations, helping to build technical capacity in previously obscure sectors of technology. Strategic reorganization also complicates certain research tasks, as any of the cases discussed in the thesis predate the existence of the Y02A. For example the new class Y02A10/26 covering “Artificial reefs or seaweed; Restoration or protection of coral reefs” makes it easier to identify new coral reef technologies, but entirely razes the prior classifications for reefs made of automobile tires, thus making it difficult to conduct searches and analyze technology in now arcane subject areas.

Other research tools are also important to note, especially digitized books, government documents, legal transcripts, used as primary source material that is made available through the United States Library of Congress (<https://www.loc.gov/>) , Hathi Trust Digital Library (<https://www.hathitrust.org/>) , internet Archive (<https://archive.org/>) and Alphabet companies Google Books (<https://books.google.com/>) which make it possible to find obsolete and obscure references required for this research project, especially those usurped or overwritten by the ongoing revisions to patent law and environmental history that dominate other sources. Collectively these resources provide nuanced histories of invention in the context of environmental policy, planning, and transformation through technological means, which in

combination with the bureaucratic systems and records of the patent system provide this thesis with a wealth of primary sources.

Climate change, and discourse on coastal adaptation and resilience situate the research in a contemporary context. Extensive prior work has been conducted in areas of coastal sustainability, policy, economics, urban planning, as well as through design speculation and analysis. This includes important contributions by researchers such as Alan Berger, Billy Flemming, and Carolyn Kousky, Kristina Hill, Guy Nordenson, Catherine Seavitt Nordenson, Jeff Carney, Traci Birch, Elizabeth Mossop, Henk Ovink, Bruce Glavovic, Fadi Mousad, Nate Kaufmann, Peter C Bosselmann, Timothy Beatley, and long list of others that provide scale, scope, and strategic insights for coastal design and planning.¹⁴ Once versed in these prior works, the Y02A patent classification scheme, and key findings of this thesis, can be understood as an ever-evolving addendum, or technical appendix, to coastal design and planning strategies already in process.

Methods developed in the thesis are highly contextual, yet not wholly unique within design discourse. Sigfried Gideon (1888-1868), the famed architectural historian and theorist, utilized patent sources to weave together an “anonymous history” in the book *“Mechanization Takes Command”* exploring the impacts of industrialization manufacturing and machine culture on daily life.¹⁵ At the time of publication in 1948 architecture and design were grappling with rapid modernization and standardization of construction systems, making primary patent

¹⁴ Kousky, Carolyn, Billy Fleming, and Alan M. Berger, eds. *A blueprint for coastal adaptation: Uniting design, economics, and policy*. Island Press, 2021.

Berger, Alan M., et al. "Theorizing the resilience district: Design-based decision making for coastal climate change adaptation." *Journal of Landscape Architecture* 15.1 (2020): 6-17.

Masoud, Fadi, ed. *Terra-sorta-firma: Reclaiming the Littoral Gradient*. Actar D, Inc., 2021.

Kauffman, Nate, and Kristina Hill. "Climate change, adaptation planning and institutional integration: A literature review and framework." *Sustainability* 13.19 (2021): 10708.

Bosselmann, Peter C. *Adaptations of the metropolitan landscape in Delta Regions*. Routledge, 2018.

Beatley, Timothy. *Blue urbanism: exploring connections between cities and oceans*. Washington, DC: Island Press, 2014.

Mossop, Elizabeth, ed. *Sustainable coastal design and planning*. CRC Press, 2018.

Nordenson, Catherine Seavitt, Guy Nordenson, and Julia Chapman. *Structures of coastal resilience*. Island Press, 2018.

Nordenson, G., Seavitt, C., Yarinsky, A., & Bergdoll, B. (2010). *On the Water: Palisade Bay*. New York: Hatje Cantz.

Birch, Traci, and Jeff Carney. "Regional resilience: building adaptive capacity and community well-being across louisiana's dynamic coastal-inland continuum." *Louisiana's Response to Extreme Weather: A Coastal State's Adaptation Challenges and Successes* (2020): 313-340.

Glavovic, Bruce, et al., eds. *Climate change and the coast: building resilient communities*. CRC Press, 2014.

de Graaf-van Dinther, Rutger, and Henk Ovink. "The five pillars of climate resilience." *Climate Resilient Urban Areas: Governance, design and development in coastal delta cities* (2021): 1-19.

¹⁵ Giedion, Sigfried, *Mechanization Takes Command a Contribution to Anonymous History*. Oxford Univ. Press 1948.

sources an appropriate reference for discussion of cultural architectural theories. Other lesser works in design use similar methods involving patent source materials. For example, a beautifully illustrated volume of the Italian journal, *Rassegna*, explores the interplay of design and patents with essay on the patented works of Le Corbusier and the role of innovation in the creation of architectural spaces and elements.¹⁶ Of course, there are also troves of books, articles, and manuscripts exploring patent innovation studies within specific technology sectors as within cultural studies and humanities. Exemplary among these is the research of Mario Biagioli, Professor of Law and Communication at the University of California Los Angeles (UCLA), who has written extensively of the politics, history, representation, and legal interpretation of patents and the patent system.¹⁷ Distinguishing the research and methods used in this thesis are the connections made between patent innovation, physical geography, coastal systems, and forward-looking climate practices in environmental design and planning. In this manner the thesis builds arguments through examination of prior-art, analysis of technologies impact on environmental systems, and outlines critical linkages between these cases, environmental policy, and framework of the Y02A patent classification in the context of coastal adaptation and resilience praxis.

¹⁶ Gregotti, Vittorio (Editor) 46 *Rassegna* (Patent and Design) - Quarterly year XIII, 46/2 - June 1991

¹⁷ Biagioli Mario et al. *Making and Unmaking Intellectual Property: Creative Production in Legal and Cultural Perspective*. University of Chicago Press 2011.

Geographical and Environmental Dimension of Patents and the Patent System

Establishment of the Y02A classification scheme is not the first time the patent system has been operationalized to help develop technologies with geographic, urban, and environmental dimensions, although it is certainly the first with a planetary scope aiming to address the wicked problems of climate change. In 1421 the Florentine government issued the first true patent to the eminent architect Filippo Brunelleschi for a ship designed to move heavy materials on the River Arno for construction the Duomo of Florence, helping to solve one of three engineering challenges associated with the building project and establishing a legal precedent for the “patent bargain” between inventors and the state.¹⁸ This myth-of-origin inextricably links the processes of urbanization and infrastructure development to the history of patent law. The anomaly of Brunelleschi’s Florentine patent established legal precedent that informed contemporaneous patent experiments in Venice, where some of the earliest precedents were those employed in public works utilizing novel technologies. Fifty-three years later the Venetian State formalized patent law with the Venetian Patent Statute of 1474, codifying the patent bargain to incentivize the sharing of new inventions in exchange for protection of intellectual property within Venetian territories.

The advent of patent law modernized the Venetian economy but was similarly entwined with environmental transformation and urbanization. The environmental flux of the Venetian lagoon created fertile ground for innovation, and in part led to establishment an equally resilient legal framework – patent law - that incentivized the evolution of technology and industry within Venetian territories.¹⁹ Many of the earliest examples of patents issued in Venice, including those predating the formal patent statute of 1474, were issued for “mud” technologies and other forms of coastal infrastructure integral to innovative public works.²⁰ This included systems used for ground stabilization, reclamation, drainage, and dredging.²¹ Perhaps the grandest and most conspicuous features of the urban landscape resulting from this process are the canals of Venice,

¹⁸ Frank D Prager, “Brunelleschi’s Patent,” *J. Pat. Off. Soc’y* 28 (1946): 109–109.

¹⁹ Hindle, “Inventing Venice: An Urban and Environmental Innovation Model from the Lagoon City.”

²⁰ Roberto Berveglieri, *Le Vie Di Venezia: Canali Lagunari e Rii a Venezia: Inventori, Brevetti, Tecnologia e Legislazione Nei Secoli XIII-XVIII* (Cierre, 1999).

²¹ Salvatore Ciriaco, *Building on Water : Venice, Holland and the Construction of the European Landscape in Early Modern Times* (New York, N.Y. ; Oxford: Berghahn Books, 2006).

built in part with innovative technology developed in partnership with private inventors through the granting of patent rights.²² Leveraging of the patent system in public works meant that innovative technologies could be tried and tested as Venice urbanized the lagoon, revealing the distinct agency of the patent system in the production of the urban landscape, and situating environmental innovations in a specific location with a “distinctly local and immediate notion of utility” as opposed to the consumer technologies that glut the patent system of today.²³

By engaging to social dimensions of innovation the Venetians were able to problem solve using diverse actors, helping to build some of the most advanced urban infrastructure of the renaissance in a dynamic coastal geography. Technology was integral to the republic, and incentives of patents, and the patent system, contributed to technology transfer to the city as the world’s leading inventors brought new discoveries from countries such as France and the Netherlands.²⁴ Expert review panels, geographically specific scopes of work, and support for prototyping new technologies was also part of the Venetian effort to build the city.²⁵ As a political act, the Venetian patent statute decoupled invention from privilege, class, and guilds, liberating inventors and democratizing ingenuity, and allowing broad constituencies to engage the processes of innovation, as anyone could be granted a patent for their invention. According to Mario Biagioli, a leading scholar of law, science, and technology, this paralleled “the demise of political absolutism, the development of liberal economies, and the emergence of the modern political subject.”²⁶ These ideas spread through Europe and the Americas and were later constitutionalized. Some legal scholars even argue that all patent law is in essence only an amendment to the original Venetian patent Statute.²⁷

Other examples exist of patent offices engaged in initiatives with geographical, atmospheric, and technological dimensions. In England, drainage of the fens in the 16th century was achieved through innovative technologies and skilled experts from the European continent,

²² Berveglieri, *Le Vie Di Venezia: Canali Lagunari e Rii a Venezia: Inventori, Brevetti, Tecnologia e Legislazione Nei Secoli XIII-XVIII*.

²³ Mario Biagioli, “Patent Republic: Representing Inventions, Constructing Rights and Authors,” *Social Research*, 2006, 1129–72.

²⁴ Klaas van BERKEL, “Cornelius Meijer Inventor et Fecit’: On the Representation of Science in Late Seventeenth-Century Rome,” 2002.

²⁵ Berveglieri, *Le Vie Di Venezia: Canali Lagunari e Rii a Venezia: Inventori, Brevetti, Tecnologia e Legislazione Nei Secoli XIII-XVIII*.

²⁶ Biagioli, “Patent Republic: Representing Inventions, Constructing Rights and Authors.”

²⁷ Craig Allen Nard and Andrew P Morriss, “Constitutionalizing Patents: From Venice to Philadelphia,” *Review of Law and Economics* 2, no. 2 (2006): 223–321.

including the Netherlands and Venice, to the British Isles. Patent rights granted by the Crown were integral to this process of technology transfer, leading to an influx of innovation and inventors.²⁸ This led to a modest technology boom in following years, with 1/5th of all patents from 1620-1640 awarded for drainage technologies to raise waters and reclaim ground.²⁹ In America, similar patterns can be observed with the patent office engaged strategically in the process of environmental transformation. The first meteorological studies in the United States were commissioned jointly by the Patent Office and Smithsonian Institution in 1855, helping to promote advances in agricultural technology and the science of climate.³⁰ The data, standards, and instrumentation developed by the Smithsonian Institution during this venture led to the creation of the a formal national weather system known as the Signal Service (1870-1891).³¹ The patent office's involvement in this meteorological research venture was also fruitful, building upon a track record of agricultural innovation that eventually led to the creation of an independent Department of Agriculture in 1862 and publication of pioneering works of agrometeorology such as "Meteorology and its Connection with Agriculture" in 1857.³² In this expanded role we see a patent office broadly concerned with the technology, data, germplasm, and cartography, that would transform western states into a vast agricultural territory.

Organization of the US patent office was central to its focus on agriculture, environment, and territorialization. From 1790 to 1849, the Patent Office was operated by the Department of State, however the increasing rate of patent submissions and an explosion of domestic concerns overwhelmed the State Department and led to the creation of the Department of Interior in 1849. The Department of Interior was formed through a strategic reorganization of the USPTO, General Land Office, Census Bureau, and Bureau of Indian Affairs and charged with the management of "home" affairs, including wilderness areas and new US territories. The combined

²⁸ Clive Holmes, "Drainage Projects in Elizabethan England: The European Dimension'," *Eau et Développement Dans VEurope Moderne* (Paris, 2004), 2004, 87–102.

²⁹ W.H. Price, *The English Patents of Monopoly*, Harvard Economic Studies (Harvard University Press, 1906),

³⁰ Patent Office. United States. Bishop, William D., Henry, Joseph, Hough, Franklin B., Coffin, James H., Smithsonian Institution., *Results of Meteorological Observations, Made under the Direction of the United States Patent Office and the Smithsonian Institution from the Year 1854 to 1859, Inclusive, Being a Report of the Commissioner of Patents Made at the First Session of the Thirty-Sixth Congress. Vol. I-II: Pt. 1.* (Washington: Govt. Print. Off., 1861).

³¹ NATIONAL ACADEMY OF SCIENCES-NATIONAL RESEARCH COUNCIL WASHINGTON DC and Hoyt Lemons, "Physical Geography" (US Government, 1953), <https://apps.dtic.mil/sti/pdfs/AD0017348.pdf>.

³² Joseph Henry, *Meteorology in Its Connection with Agriculture.*, p. 455-492, 419-[552; 461]-524 incl. diagrs., illus.tables. ([Washington, D. C., 1857), //catalog.hathitrust.org/Record/012307539.

interests of the Department of Interior made it the de facto department of the west, playing a vital role in the expansion and development of western states. Richard Andrews, an environmental policy scholar, has argued that in an ideal world, the integration of interior, patent, land, and census departments might have provided the “foundation for integrated planning and management of the nation’s environment.”³³

As history shows, the sociotechnical aspects of innovation and organization of the patent systems have environmental implications and can be operationalized to enact environmental works at a grand scale, draining lands, building productive agricultural systems, urbanizing lagoons, tracking data, and altering deltaic landscapes, by integrating sociotechnical aspects of innovation large-scale works of urbanization and development. The Y02A is the latest iteration, conceived to address the global challenges of climate adaptation with a strategic focus on green & blue urban infrastructure, coastal systems, agriculture, and technologies for mapping and sensing the environment, etc., built from a contemporary perspective of ecology, sustainability, and intelligence. Among the many challenges facing this initiative is the translation of technology into actionable projects that impact the lives of coastal populations. This “last mile” problem highlights the potential contribution of the allied professions of environmental design and planning to this endeavor as both end user, and producer, of new technologies.

³³ R N L Andrews, *Managing the Environment, Managing Ourselves: A History of American Environmental Policy* (Yale University Press, 1999)

Framing

Operationalization means to put something into operation or use. In the context of coastal resilience and adaptation operationalization means the real-world application of planning frameworks/theories and tangible benefits for coastal communities and the environment. According to recent compendium on urban resilience for risk and adaptation governance focusing on the on applications of resilience planning theory and practice, “operationalising resilience is arguably one of the most impactful global issues for the future research as it implies to link the concept about what urban resilience is and what urban resilience ought to be.”³⁴ A broader survey of literature reveals an array of established pathways to operationalize resilience and adaptation goals in the coastal systems and the built environment. In summary this includes funding, policy, land-use planning, design competitions, theorization of decision-making units, and grass roots organizing, etc., that effectively translate theory into practice.³⁵ Although the list of operational pathways is robust, and evolving, research in this area largely overlooks the role of technological innovation. This is surprising as global policy initiatives such as the 2015 Paris Agreement of Climate Change make explicit provisions for technological innovation and technology transfer with tangible implications for coastal adaptation and resilience efforts.

Obviously, these pathways continue expand and are not without controversy. Some argue that the theoretical frameworks for adaptation and resilience are too poorly defined for use in site-specific situations and ecosystems.³⁶ Others cite the need for stronger institutions for projects to be realized.³⁷ Specific industries, such as building sectors, may also struggle to implement overly theoretical resilience planning and policy initiatives that challenge industry

³⁴ Ombretta Caldarice, Grazia Brunetta, and Nicola Tollin, “The Challenge of Urban Resilience: Operationalization,” in *Urban Resilience for Risk and Adaptation Governance* (Springer, 2019), 1–6.

³⁵ Alan M Berger et al., “Theorizing the Resilience District: Design-Based Decision Making for Coastal Climate Change Adaptation,” *Journal of Landscape Architecture* 15, no. 1 (2020): 6–17; Britta Horstmann, “Operationalizing the Adaptation Fund: Challenges in Allocating Funds to the Vulnerable,” *Climate Policy* 11, no. 4 (2011): 1086–96; Helen Lochhead, “Resilience by Design: Can Innovative Processes Deliver More?,” *Procedia Engineering* 180 (2017): 7–15.

³⁶ Marcus Sheaves et al., “Principles for Operationalizing Climate Change Adaptation Strategies to Support the Resilience of Estuarine and Coastal Ecosystems: An Australian Perspective,” *Marine Policy* 68 (2016): 229–40.

³⁷ Sierra C Woodruff et al., “Adaptation to Resilience Planning: Alternative Pathways to Prepare for Climate Change,” *Journal of Planning Education and Research*, 2018, 0739456X18801057; Md Shamsuzzoha, Md Rasheduzzaman, and Rajan Chandra Ghosh, “Building Resilience for Drinking Water Shortages through Reverse Osmosis Technology in Coastal Areas of Bangladesh,” *Procedia Engineering* 212 (2018): 559–66.

conventions and use ambiguous terminology.³⁸ In the context of this dissertation, one area of further consideration is the role of actors and agents operating within coastal social-ecological-technical systems (SETs), and the mechanisms through which to engage the process of innovation in coastal works. Presciently, the Y02 patent classification scheme aims to operationalize technical aspects of global climate policy through the management of complex societal and technical responses to climate change – building adaptive capacity while catalyzing innovation.

According to the European Patent Office description “This class (Y02) covers selected technologies, which control, reduce or prevent anthropogenic emissions of greenhouse gases [GHG], in the framework of the Kyoto Protocol and the Paris Agreement, and also technologies which allow adapting to the adverse effects of climate change.”³⁹ As noted in the United Nations Framework Convention of Climate Change (UNFCCC) program page, The Paris Agreement includes provision for advancing technology development and transfer of technology to build capacities in climate resilience. This includes a framework for enhanced technological capacity within climate adaptation and mitigation sectors through leveraging intellectual property and technology transfer.⁴⁰ Accordingly, the Y02 scheme initially focused on carbon technologies and climate mitigation, however the categories of climate adaptation technology continue to expand and now include an broad range of urban and environmental technologies related to the built environment and coastal systems – presenting a distinct opportunity to advance technological capacity in these sectors.

Fundamentally, the Y02A scheme aims to link the socio-technical aspects of innovation to the process climate adaptation. The invention and diffusion of technology is, and will be, integral to operationalizing resilience and adaptation goals through the integration of novel technologies into real world project that impact coastal communities and ecosystems. We needn’t look any further than smart-cities and the “Internet of Things” approach to urban

³⁸ Margaret H Kurth et al., “Defining Resilience for the US Building Industry,” *Building Research & Information* 47, no. 4 (2019): 480–92.

³⁹ “Espacenet – Patent Classification,” accessed February 8, 2021, <https://worldwide.espacenet.com/patent/cpc-browser#!/CPC=Y02A>.

⁴⁰ Chen Zhou, “Can Intellectual Property Rights within Climate Technology Transfer Work for the UNFCCC and the Paris Agreement?,” *International Environmental Agreements: Politics, Law and Economics* 19, no. 1 (2019): 107–22; Matthew Rimmer, “Beyond the Paris Agreement: Intellectual Property, Innovation Policy, and Climate Justice,” *Laws* 8, no. 1 (2019): 7.

problem solving to realize how deeply integrated technology has become with sustainability measures and cities.⁴¹ In the context of coastal adaptation and resilience this represents an exciting new frontier, translating theory into action through novel technology.

The complex phenomenon of technological and infrastructural change is not an abstraction, in fact it permeates people's daily lives in, or away, from coastal regions. Take for example the current transformations to cities and urban life undertaken by digital technology companies such as Uber, Amazon, Google, etc., who are reformatting transportation, logistics, and modes of production, in the United States and globally to serve their missions. The new technologies, and their delivery method, are brought to the urban realm through processes beyond the conventional scope of the allied urban disciplines and therefore appear as disruptive, with many cities often caught off-guard by fleets of new amateur taxi drivers, electric scooters, and online shopping. A 2018 New York Times article titled "Tech Envisions the Ultimate Start-Up: An Entire City" highlights the issue clearly by spotlighting the role large technology companies such as Uber, Amazon, and Google play in development of the contemporary American city and their vision for future.⁴² The issue has recently reached a precipice with SideWalk Labs, an Alphabet Company, attempting to build an entire urban district in Toronto Canada, and later abandoned the project due to privacy concerns and public resistance.⁴³ Innovation driven urbanism has infiltrated contemporary society, challenging conventional approaches to infrastructure while simultaneously revealing the capacity for step change through technological innovation in the hardware and software that we use to build cities.

The Y02A exist as a provocation that these step changes may also occur in core environmental technologies and climate adaptive infrastructure such as green infrastructure, coral reef restoration, plastic pollution mitigation, and a range of other sectors covered by the classification scheme. Patents and the global patent systems have well established relationships

⁴¹ David Perez Abreu et al., "A Resilient Internet of Things Architecture for Smart Cities," *Annals of Telecommunications* 72, no. 1–2 (2017): 19–30; Michael Batty et al., "Smart Cities of the Future," *The European Physical Journal Special Topics* 214 (2012): 481–518; Ruben Sánchez-Corcuera et al., "Smart Cities Survey: Technologies, Application Domains and Challenges for the Cities of the Future," *International Journal of Distributed Sensor Networks* 15, no. 6 (2019): 1550147719853984.

⁴² Emily Badger, "Tech Envisions the Ultimate Start-Up: An Entire City," *The New York Times*, February 24, 2018, sec. The Upshot, <https://www.nytimes.com/2018/02/24/upshot/tech-envisions-the-ultimate-start-up-an-entire-city.html>.

⁴³ "Alphabet's Sidewalk Labs Scraps Its Ambitious Toronto Project," *Wired*, accessed November 13, 2020, <https://www.wired.com/story/alphabets-sidewalk-labs-scraps-ambitious-toronto-project/>.

to invention and diffusion of new technology and are arguably the most robust institutional mechanism for the management of sequential innovation. Western patent law was founded on the principles that patents would incentivize invention and disclosure of new technologies to improve society.⁴⁴ Critics argue that the patent system inhibits innovation, or is exploited and does not achieve its stated goals due to red tape, therefore inhibiting certain innovations.⁴⁵ Yet, many have forgotten that the origins of patent law and the “patent bargain” (i.e. a quid pro quo in which the inventor discloses an invention in order to receive patent protection from the state) on which the system was founded were highly egalitarian and have been employed in public works since their inception.⁴⁶ Irrespective of contemporary debates on the subject, the patent system is the oldest institutional and bureaucratic framework for the management of sequential innovation – playing a role in innovation in all sectors of technology.⁴⁷ Operationalizing the patent system in service of global climate adaption efforts is one step in a broader societal change, with upsides for the creation of knowledge infrastructure and coordination of innovation in emergent environmental sectors such as those converging in coastal anthromes.

The benefits of invention, disclosure, and cataloging new technologies is manifold. The disclosure of new inventions leads to the creation of knowledge infrastructure which is vital to emerging and established sectors of technology alike. Technological innovation, and by proxy the patent system, ask open ended questions about the future of technology and provide institutional framework to organize, categorize, and disseminate knowledge.⁴⁸ Since the inception of patent law categorization of technology has kept pace with technological innovation to effectively collate and disseminate technological information and the preservation of patent rights.⁴⁹ Archiving and diffusion of technical information is essential to the system. As with other

⁴⁴ Suzanne Scotchmer, “Patents as an Incentive System,” in *Economics in a Changing World* (Springer, 1996), 281–96.

⁴⁵ Adam B Jaffe and Josh Lerner, *Innovation and Its Discontents: How Our Broken Patent System Is Endangering Innovation and Progress, and What to Do about It* (Princeton University Press, 2011).

⁴⁶ Mario Biagioli, “From Print to Patents: Living on Instruments in Early Modern Europe,” *History of Science* 44, no. 2 (2006): 139–86; Biagioli, “Patent Republic: Representing Inventions, Constructing Rights and Authors”; Mario Biagioli, “Patent Specification and Political Representation: How Patents Became Rights,” *Making and Unmaking Intellectual Property: Creative Production in Legal and Cultural Perspective*, 2011, 25–40.

⁴⁷ Nard and Morriss, “Constitutionalizing Patents: From Venice to Philadelphia.”

⁴⁸ Carlo Belfanti, “Guilds, Patents, and the Circulation of Technical Knowledge: Northern Italy during the Early Modern Age,” *Technology and Culture* 45, no. 3 (2004): 569–89.

⁴⁹ Heather J E Simmons, “Categorizing the Useful Arts: Part, Present, and Future Development of Patent Classification in the United States,” *Law Libr. J.* 106 (2014): 564–564; MF Bailey, “History of Classification of Patents,” *J. Pat. Off. Soc’y* 28 (1946): 463.

complex and adaptive systems, technological innovations develop and progress in distinct ways leading to novel combinations and permutations. This adaptive quality is highly desirable as the vanguard of technology is continuously redefined. Aptly, the patent system is theorized to operate like a “process of recombinant search over technology landscapes” in which iterative processes of revision and investigation lead to novel inventions.⁵⁰ Integral to this conceptualization is the process of query, recombination, and redefinitions through which discovery occurs and new categories of technology emerge such as those integral to coastal adaptation and resilience and others now organized through the Y02A classification scheme. Coordinating the diffusion of innovation in coastal adaptation and resilience technologies may help bridge the innovation chasm and greenlight actionable technology as new policies and plans are implemented. Importantly, innovations can then be further leveraged and fast-tracked in critical sectors such as green technology.⁵¹ As coastal adaptation and resilience policies and plans proliferate, so too will the need for innovation.

However nascent, knowledge regarding the unique role of intellectual property in resilience and adaptation is gaining. For example, in the context of smart cities researchers have observed that regions with smart cities plans have higher incidence of innovation generally and an increase in the patenting of specific technologies for smart city applications.⁵² The fact that smart cities develop more smart city technologies is an important revelation. The findings link established research on the geographical determinants of innovation to the process of invention that will define future smart cities.⁵³ Evidence also exists that an effective patent system facilitates resilience through the transfer of environmentally sensitive technology from advanced economies to least developed countries.⁵⁴ This means that technologies developed in one region can effectively be transferred to other regions as needed which is vital given the scale and scope

⁵⁰ Lee Fleming and Olav Sorenson, “Technology as a Complex Adaptive System: Evidence from Patent Data,” *Research Policy* 30, no. 7 (2001): 1019–39.

⁵¹ Eric L Lane, “Building the Global Green Patent Highway: A Proposal for International Harmonization of Green Technology Fast Track Programs,” *Berkeley Technology Law Journal*, 2012, 1119–70.

⁵² Caragliu and Del Bo, “Smart Innovative Cities: The Impact of Smart City Policies on Urban Innovation.”

⁵³ For an expanded discussion on “geographies of innovation” see Feldman and Florida Maryann P Feldman and Richard Florida, “The Geographic Sources of Innovation: Technological Infrastructure and Product Innovation in the United States,” *Annals of the Association of American Geographers* 84, no. 2 (1994): 210–29; Harald Bathelt, Maryann Feldman, and Dieter F Kogler, *Beyond Territory: Dynamic Geographies of Innovation and Knowledge Creation* (Routledge, 2012).

⁵⁴ Azam, “Climate Change Resilience and Technology Transfer: The Role of Intellectual Property.”

of the global climate crisis and necessity for new forms of critical infrastructure. The Y02A classification scheme, and provisions for technological innovation in the Paris Agreement, take steps to better coordinate diffusion of technical knowledge, creating a distinct opportunity to expand technical capacities.

Of course, open-source mechanisms and intellectual property will both play a role in adaptation and resilience technology. This does not diminish the importance of either, in fact they operate complimentary to each other. In many cases, innovation within the adaptation and resilience problem space will undoubtedly be shared, disseminated, and operationalized through open source, and open innovation, mechanisms. Based on observations in contemporary popular media and peer-reviewed literature, this will likely lead to advances through the sharing of data sets, planning methodologies, social networks, and application of new technologies such as artificial intelligence promoted by Open AI, Code For Change, and Code for Change.⁵⁵ In general an 'Open Source model' refers to collaborative mode of production in which innovation is shared more openly and an 'Open Innovation models' refers to a process in which a firm integrates ideas from inside and outside to innovate.⁵⁶ Preliminary research into the role of such open source methods in climate mitigation technology does outline clear pathways for technology transfer using Open Innovation and Open Source methods through licensing agreements of Intellectual property Rights (IPR) and creation of General Public Licenses (GPL) in addition to conventional licensing and sharing of technology through patent pools, patent commons, and alternative structures such as Equitable Access Licensing and clearing houses for eco-technology.⁵⁷ Importantly, all of these modified arrangements are built on models for shared and distributed intellectual property that do not negate the need for management of sequential innovation and inventors rights, such as those managed by the traditional patent system.

⁵⁵ "Code for America," Code for America, accessed March 10, 2023, <https://codeforamerica.org/>; "OpenAI," accessed March 10, 2023, <https://openai.com/>; "Code for Change," accessed March 10, 2023, <https://codeforchangenepal.com/>.

⁵⁶ For an in-depth description see: H.W. Chesbrough, *Open Innovation: The New Imperative for Creating and Profiting from Technology*, G - Reference, *Information and Interdisciplinary Subjects Series* (Harvard Business School Press, 2003).

⁵⁷ Krishna Ravi Srinivas, "Role of Open Innovation Models and IPR in Technology Transfer in the Context of Climate Change Mitigation," *Diffusion Of Renewable Energy Technologies: Case Studies Of Enabling Frameworks In Developing Countries-Technology Transfer Perspective Series*, 2011, 147–58.

Future Technologies for Future Coasts

Coastal resilience and adaptation frameworks establish new theoretical horizons for the nature of social-ecological-technical interactions in coastal systems. However, the translation of resilience and adaptation theory into tangible technologies is underrepresented in literature. In other “innovation rich” sectors the invention of new technology is well documented and theoretical models have been developed to help comprehend this process. For example, in the fields of biomedical technology knowledge translation and theoretical framework of the Knowledge To Action (KTA) model is explored as a pathway to invention.⁵⁸ The KTA model hypothesizes the translation of inquiry and knowledge synthesis into actionable tools and technologies. Other researchers in the same field theorize that author-inventor relationships are central to the process of biomedical invention as new technologies are developed through innovative publications/research that led to new discoveries.⁵⁹ In this formulation of inventive process key authors in a particular area of expertise are also key inventors as indicated by publication lists and patents. Irrespective of the pathway to invention, the theoretical framing seeks the same outcome, namely, the identification of a need or purpose for an invention and the creation of a means that can satisfy this need or purpose.⁶⁰ In context of coastal adaptation and resilience, the pathways to action are often conceived of primarily through the professional lens of planning, architecture, and design, however the problem space can also be approached through productive partnership with technology and the processes of innovation. The establishment of the Y02A exists as a framework to support these activities, and a provocative call-to-action for practitioners, researchers, and communities.

The value of engaging innovation in the resilience and adaptation sector is twofold. Firstly, new technologies are developed, and secondly the categorization of these discoveries lead to the codification of knowledge and increased linkages between ideas. A general theory of invention suggests that searching is the essential framework for discovery involving the iterative

⁵⁸ Joseph P Lane and Jennifer L Flagg, “Translating Three States of Knowledge—Discovery, Invention, and Innovation,” *Implementation Science* 5, no. 1 (2010): 1–14.

⁵⁹ ECM Noyons et al., “Exploring the Science and Technology Interface: Inventor-Author Relations in Laser Medicine Research,” *Research Policy* 23, no. 4 (1994): 443–57.

⁶⁰ W Brian Arthur, “The Structure of Invention,” *Research Policy* 36, no. 2 (2007): 274–87.

and recursive stages of stimulus, net casting, categorization, linking, and discovery.⁶¹ Other researchers suggest that novelty or newness is essential to the process of invention and the combinatorial process and refinement of existing technologies are fundamental to the creation of new technologies.⁶² Central to the combinatorial process is context and prior knowledge. In this context the patent is known to serve as a “carrier” of innovation leaving “footprints” for the development of new technology.⁶³ Invention of a new technology is important within itself, but the process of invention also contributes to knowledge infrastructure and the evolution of innovations in diverse sectors and across spatial scales.⁶⁴ Most of what is known in relation to these knowledge infrastructures is derived from innovation rich sectors of technology and industry. But, in the context of the Anthropocene, these knowledge infrastructures are theorized to have the capacity to contribute to “large-scale, long-term, anthropogenic environmental change.”⁶⁵ Leveraging knowledge infrastructure may also help solve intractable problems such as those converging in coastal regions globally by linking the iterative process of invention to the dynamics of coastal systems.

Reformatting the enmeshed technological systems of coastal anthromes to achieve adaptation and resilience goals will require cross-sectoral strategies, ranging from coordinated blue/green infrastructure investment to new crop management practices, social media, and distributed reverse osmosis systems.⁶⁶ Translation of adaptation and resilience theory into applicable technologies may fill this gap and imagine new forms of coastal infrastructure and an expanded coastal infrastructure toolkit. Adaptation and Resilience literature indicates the need

⁶¹ Patrick G Maggitti, Ken G Smith, and Riitta Katila, “The Complex Search Process of Invention,” *Research Policy* 42, no. 1 (2013): 90–100.

⁶² Deborah Strumsky and José Lobo, “Identifying the Sources of Technological Novelty in the Process of Invention,” *Research Policy* 44, no. 8 (2015): 1445–61.

⁶³ Hyejin Youn et al., “Invention as a Combinatorial Process: Evidence from US Patents,” *Journal of the Royal Society Interface* 12, no. 106 (2015): 20150272.

⁶⁴ Frank Moulaert and Abdelillah Hamdouch, “New Views of Innovation Systems: Agents, Rationales, Networks and Spatial Scales in the Knowledge Infrastructure,” *Innovation: The European Journal of Social Science Research* 19, no. 1 (2006): 11–24.

⁶⁵ Paul N Edwards, “Knowledge Infrastructures for the Anthropocene,” *The Anthropocene Review* 4, no. 1 (2017): 34–43.

⁶⁶ Justin Joyce et al., “Coupling Infrastructure Resilience and Flood Risk Assessment via Copulas Analyses for a Coastal Green-Grey-Blue Drainage System under Extreme Weather Events,” *Environmental Modelling & Software* 100 (2018): 82–103; Shamsuzzoha, Rasheduzzaman, and Ghosh, “Building Resilience for Drinking Water Shortages through Reverse Osmosis Technology in Coastal Areas of Bangladesh”; Ranjan Roy et al., “Resilience of Coastal Agricultural Systems in Bangladesh: Assessment for Agroecosystem Stewardship Strategies,” *Ecological Indicators* 106 (2019): 105525.

for innovation and an expanded repertoire of coastal technologies.⁶⁷ Therefore, building technological pathways from, and within, the sector is a natural progression of the social, scientific, and planning/design frameworks emerging from coastal networks.

Integrating technological and social change into future planning frameworks requires anticipation of the unknown and acknowledgment that new technologies emerge through complex sociotechnical processes as we progress towards an uncertain future.⁶⁸ Anticipatory frameworks for managing acceleration and complexity are essential in sectors ranging from national defense to emergent technologies.⁶⁹ Anticipatory governance is defined as “a broad-based capacity extended through society that can act on a variety of inputs to manage emerging knowledge-based technologies while such management is still possible. It motivates activities designed to build capacities in foresight, engagement, and integration – as well as through their production ensemble.”⁷⁰ Beyond the technological, anticipatory governance is integral to social-ecological resilience and suggest that effective management of this process can lead to increased ecological knowledge.⁷¹ A central tenant of anticipatory governance is the recognition of values associate with emergent technologies and their role in society in sectors ranging in scale from nanotechnology to geoengineering.⁷² Foresight is integral to anticipatory governance as institutions establish future trajectories for investment and innovation.⁷³ Technological innovation and patent trends offer distinct insights about future environmental scenarios while simultaneously revealing the role of the patent system of adaptive governance and new knowledge infrastructures.

However optimistic, the desire for coastal innovation does reveal a paradox in that we must invent new technologies and social structures while realizing that technology and culture is

Julie L Davidson et al., “Interrogating Resilience: Toward a Typology to Improve Its Operationalization,” *Ecology and Society* 21, no. 2 (2016); Klein et al., “Technological Options for Adaptation to Climate Change in Coastal Zones.”⁶⁷ Klein et al.

⁶⁸ Carla Alvial-Palavicino, “The Future as Practice. A Framework to Understand Anticipation in Science and Technology,” *TECNOSCIENZA: Italian Journal of Science & Technology Studies* 6, no. 2 (2016): 135–72.

⁶⁹ Leon Fuerth, “Operationalizing Anticipatory Governance,” *Prism* 2, no. 4 (2011): 31–46.

⁷⁰ David H Guston, “Understanding ‘Anticipatory Governance,’” *Social Studies of Science* 44, no. 2 (2014): 218–42.

⁷¹ Emily Boyd et al., “Anticipatory Governance for Social-Ecological Resilience,” *Ambio* 44, no. 1 (2015): 149–61.

⁷² Risto Karinen and David H Guston, “Toward Anticipatory Governance: The Experience with Nanotechnology,” in *Governing Future Technologies* (Springer, 2009), 217–32; Rider W Foley, D Guston, and Daniel Sarewitz, “Towards the Anticipatory Governance of Geoengineering,” *Geoengineering Our Climate*, 2015.

⁷³ Jose M Ramos, “Anticipatory Governance: Traditions and Trajectories for Strategic Design,” *Journal of Futures Studies* 19, no. 1 (2014): 35–52.

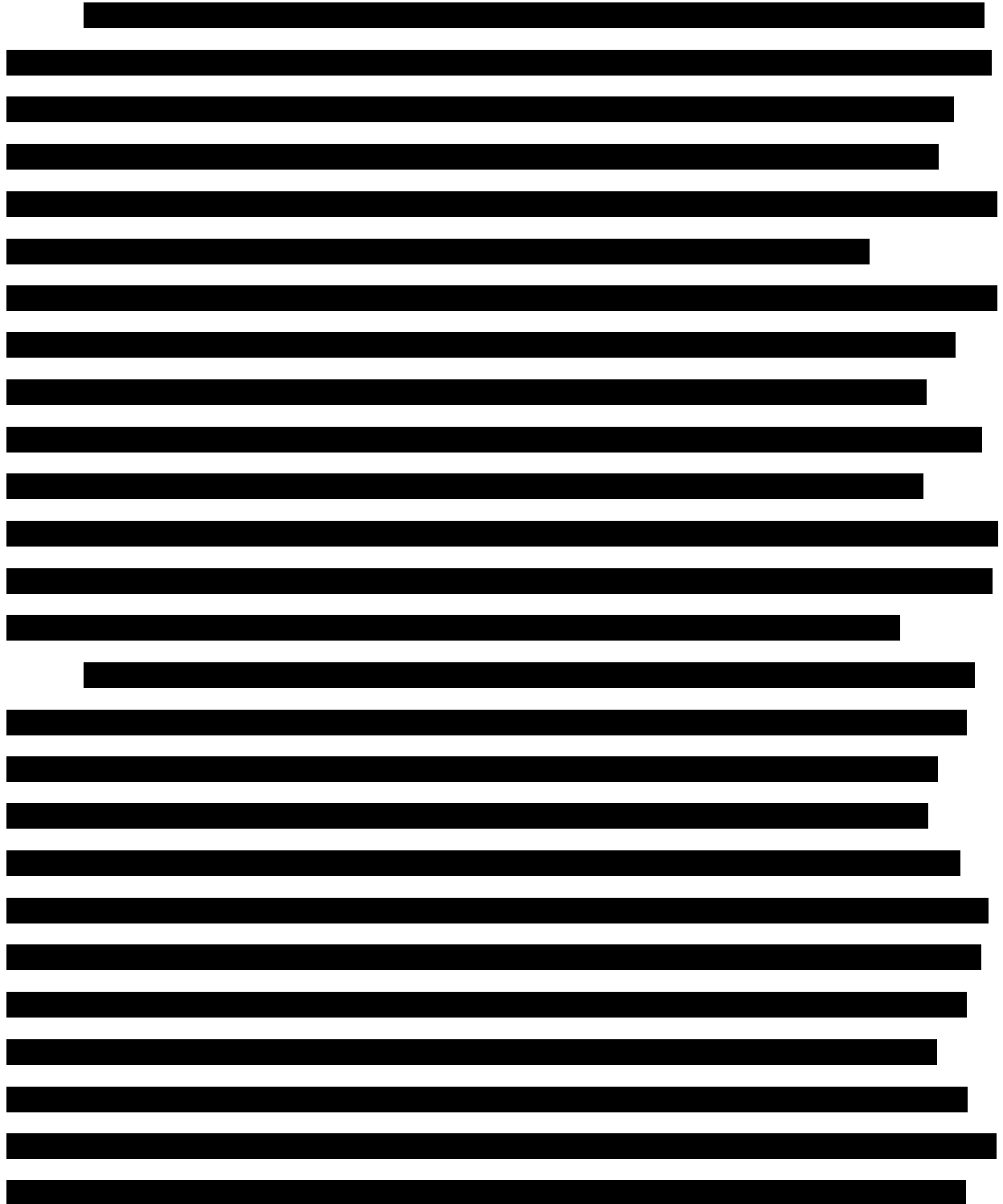
responsible for many of the declines of coastal ecological health and process. Bruce Glavovic refers to this *problematique* as the “coastal innovation paradox” in which we must innovate for our future survival but must also recognize how past innovations and systems have led us to the present situation.⁷⁴ This paradox is ripe within the proposal to leverage patent innovation to advance coastal adaptation and resilience, however an alternative reading of patent history and an analysis of case studies presented in this thesis showcase the positive contribution of innovation to our coastal future.

The paradoxical nature of coastal innovation has the potential to instigate change in both the technologies and culture of coastal regions. New decision-making units, cultural efforts, and democratic processes are spearheading changes in coastal environments and new technologies will parallel these initiatives. This involves a critical reassessment of coastal infrastructure to embrace concepts modularity, flexibility, and autonomy, etc.⁷⁵ Paradigm shifts are afoot and readily observable in international design and planning competitions, pedagogical initiatives, and student work at leading universities, and in coastal masterplans produced by government agencies. At this juncture in history a distinct opportunity exists to leverage the patent systems, and patented technology, to advance and operationalize these new paradigms in planning and design praxis. As is argued in this thesis, the patent system offers a distinct form of agency in coastal systems and can contribute to democratic and technological modes of coastal adaptation and resilience by engaging diverse constituents, flattening pathways for innovation, coordinating innovation, and broadening the toolkit of coastal technologies.

⁷⁴ Bruce C Glavovic, “Coastal Innovation Paradox,” *Sustainability* 5, no. 3 (2013): 912–33.

⁷⁵ Bruce C Glavovic, “Coastal Innovation Imperative,” *Sustainability* 5, no. 3 (2013): 934–54; Louisa Marie Shakou et al., “Developing an Innovative Framework for Enhancing the Resilience of Critical Infrastructure to Climate Change,” *Safety Science* 118 (2019): 364–78; Bradley Cantrell, Laura J Martin, and Erle C Ellis, “Designing Autonomy: Opportunities for New Wildness in the Anthropocene,” *Trends in Ecology & Evolution* 32, no. 3 (2017): 156–66.

1. Inventing Oyster-tecture: Dimensions of an Innovation Chasm in Coastal Adaptation and Resilience Technologies



2. A wild goose chase? The search for alternative coastal stabilization technologies and the emergence of new actor-networks

Stabilization of the coastline has paralleled the development of ports, cities, shipping routes, and military sites, for millennia. Today, coastal stabilization is a global issue gaining relevancy through widespread coastal development, increased sea level rise, storm surges, and other climate change induced threats to coastal development. However, the logic of rigidly armoring dynamic coastal systems is widely criticized as appreciation grows for coastal processes and the environmental impacts of rigid structures become clear. The limits of existing technologies, and the ongoing coastal changes occurring globally in the context of climate change, necessitate a search for alternative technologies. This proverbial “wild goose chase” has led to the advent of diverse range of novel processes for coastal stabilization while simultaneously revealing the challenge of innovating within complex environmental systems. Irrespective of the challenges, the search for novel coastal stabilization technologies reveals a range of inventors, new technologies, corporations, communities, awards organizations, and institutions, engaged in the invention prototyping, and implementation of coastal works.

As the word “alternative” implies the search for novel coastal stabilization technologies inherently challenges entrenched techniques and protocols developed over centuries - engaging diverse human and non-human actors in coastal systems, forging new networks, and leading to establishment of new technological assemblages operating within coastal Anthromes. Their novelty, failures, and success, make these new assemblages interesting to consider as we approach the wicked problem of global sea level rise with no established government or private sector entity fully prepared to address the scale and complexity of this emergent global issue. Reflecting on this process through the lens of actor network theory reveals patent documents, as their associated rights, as important intermediaries through which innovative solutions to coastal stabilization techniques are realized. Research on patented technologies therefore highlights the actors-networks engaged in this process of instigating change, and challenging entrenched interests of agencies such as the United States Army Corps of Engineers (USACE), who hold near monopolies on coastal works in the United States.

‘marinovation’ partners through the Ensei program – a scheme that helped seed similar programs and technology in the United States. An argument could be made that programs such as Ensei and the United States National Artificial Reef Plan, further consolidating power in large corporate interests or within government, overlooking key socio-technical aspects of innovation. Conversely, optimists will see the potentiality in government sponsored programs and partnerships to build ecological systems at oceanic scales and look towards the lessons learned as the next wave of coastal development plans are unfurled.

A counter view to the possibility of centralized corporate power, offered in chapters 2 & 3, explores how networks of outsiders, individuals, experts, and institutions can instigate change within corporate and government monopolies through intellectual property rights, challenging entrenched power structures and catalyzing change in coastal systems – with outcomes that range from transformational works proposed in the Mississippi Delta by Haupt and Eads, to the messy and unsuccessful installation of seascape artificial seaweeds at Cape Hatteras. These historical accounts not only show how innovation, politics, and policy transform large-scale environmental systems, they serve as a template for the struggles of the future in which novel coastal adaptation resilience technologies of the future are tested and implemented. Since coastal systems exist within a contested problem space, any new technology must confront the entrenched powers of entities such as the USACE, with patent rights operating as an intermediary and “stick” through which to instigate new networks and catalyze change.

In the following chapters (4-6) the opportunities and potentiality of integrating the patent system (i.e. Y02A, data, forecasting, infrastructure, law) and innovative patented technologies into environmental design and planning praxis are explored. Integration of the Y02A scheme with praxis presents distinct challenges, however the opportunity builds knowledge infrastructure, projects new technological futures, and translates theory into action, are great and warrant deep consideration from professions steeped in traditions of “best practices” and precedent, which are sometimes contradictory to open systems of innovation and technological exchange. Hybrid vigor resulting from the union of global sociotechnical processes and localized sites and design/planning practices challenges convention and points towards the emergence of an innovation model. Ultimately, the proceeding chapters argue that the

potentiality of the Y02A classification scheme will be unlocked through future technological pathways for coastal adaptation and resilience in enables, and the operationalization of these pathways through professional practices of the allied professions of environmental design and planning. Since no instruction manual exist for the adaptation of coastal systems in the face of climate change, the living repository of technology coordinated by the Y02A has the capacity to link the adaptive capacity of technology to site and urban systems through the allied disciplines of environmental design and planning.

4. Knowledge Infrastructure for Coastal Infrastructure: utilization of patent innovation studies in the Bay Area Resilience by Design Challenge.

Patent documents have been archived for six centuries globally and provide a valuable dossier of technological knowledge in every sector of the known Technosphere, including environmental technologies that are used to engineer, map, and inhabit coastal regions. The enormity of the global patent archive, now estimated to exceed 140 million searchable documents, is astounding and is among the world's largest technological databases and a robust form of knowledge infrastructure. Obviously, the primary function of the patent system is bureaucratic management of sequential innovation and establishment of legal rights for inventors. However, the patent system's capacity for search, citation, image archiving, and language translation also serves as a repository of technical knowledge and providing deep insights about current innovation, past discoveries, and future trends.

Technical information in patent documents is communicated through visual representations, or projections, of technology that simultaneously reveal the functioning of an invention whilst creating distinct challenges with regards to applicability and performance of untried technology. Within this dialectic between representation and application, design and planning professions have the opportunity to translate and evaluate novel technology, foregrounding novel systems through their integration in planning processes and design proposals. As is observed in chapter 1 through the advent of oyster-ecture, the development and application of novel environmental technology presents challenges of prolonged project timelines, siloed inventor groups, and incongruencies in the exchange of technical information that may lead to an innovation chasm and other bottlenecks that inhibit the realization of new technology in the built environment. Engaging the global patent archive during coastal adaptation planning processes has the potential to address some of these concerns, linking real-world sites and coastal systems to innovative knowledge infrastructure.

During the 2017 Resilience By Design Bay Area Challenge in California, the Common Ground Team integrated patent data and technical specifications into the design process to help

develop site planning strategies for deltaic restoration, ecological enhancement, and transportation infrastructure. The team was composed landscape architects, planners, architects, ecologists, and other consultants, including Richard Hindle (author) who contributed expertise regarding patents and helped build technical dossiers for use by the design team. Translations between technical dossiers, detailed designs, and overarching site planning strategies helped advance the project through heuristic problem solving and led to proposals for creative landscape systems for the degraded San Pablo Baylands; including a living benthic research lab and novel sediment capture systems to build ground. This chapter offers a critical reflection and detailed analysis of the year-long design process to better understand how patents, and their associated knowledge infrastructure, can contribute to coastal adaptation and resilience design and planning processes. As part of this analysis, special attention is given to the modes representation through which technical information is communicated and the systems of search, classification, and citation, that organize provide access to patent data. Since there is no “construction manual” or “best practices” for complex sites facing subsidence, liquefaction, sediment deficits, ecological degradation, ongoing development pressures, the repository to novel patented inventions facilitated rapid iterations and provided references for the design process. This contrasts with more conventional modes of praxis in which a series of expert consultants (i.e. ecological, soil, hydrology, geotechnical, transportation) provide feedback and review of design iterations and phased plans. Although these experts were also part of the Common Ground Team, the introduction of “other” knowledge, and technical concepts from broad networks of inventors, remixed the workflow and allowed for heterogenous ideas to be considered as part of the design phases.

During the yearlong competition process, the technical dossiers evolved, facilitating design iterations and the refinement of the site’s final masterplan, however the process left many questions unanswered regarding testing, implementation, and viability of the speculative systems when reduced to practice and integrated into a site during construction phases. To address the questions of testing and evaluation in the site’s long-term evolution, the team proposed a “living lab” to be built on the site to research, test, and evaluate, key technological systems operating on the site, allowing the team to bridge between the two distinct realms of

global innovation and site-specific design strategies. Of course the proposal does not solve the real-world challenges of construction, testing, and viability of untried technology. In the dialectic between design proposals utilizing innovation technology, and the implementation these novel technologies in real-world sites, important issues are raised regarding the timescales of landscape design and construction and pathways through which to ensure innovative environmental technologies reach vulnerable sites and communities responsibly through planning and design praxis. A foundational step in this process is the exchange of technical information and the translation of this technical information into viable design proposals. The Y02A classification scheme has the potential to operate as knowledge infrastructure in support of these efforts, helping to inform planning and design process through the searching and archiving of prior-art and rapid diffusion of new advances in coastal technologies that address the adaptation and resilience challenges of the future.

Knowledge Infrastructures

Knowledge infrastructure is defined by Paul Edwards as “robust networks of people, artifacts, and institutions that generate, share, and maintain specific knowledge about the human and natural worlds.”²⁴⁵ In essence these infrastructural systems are complex networks of information/knowledge intertwined with social, technical, and environmental systems, with radical implications for the way society perceives and manages the world. As the word “infrastructure” implies the knowledge systems serve as substructures supporting other systems, and are enmeshed with society, economy, energy, material use, politics, and the management of complex environmental systems. Climate change data, for example, reveals the ongoing relationship between the technologies used to map and model the environment and our understanding of a changing planet. The interrelation of data, technology, science, and society through which we comprehend a changing planet represents as a form of ‘climate knowledge infrastructure’ that shape our management of the environment.²⁴⁶ Similarly, in agricultural

²⁴⁵ Paul N. Edwards, *A Vast Machine : Computer Models, Climate Data, and the Politics of Global Warming* (Cambridge, Mass.: MIT Press, 2010). p. 17

²⁴⁶ Edwards.

sectors knowledge infrastructure is essential to the dissemination of technical knowledge and data, leading to changes in industry and large-scale land management strategies.²⁴⁷

Most of what is known of knowledge infrastructure is derived from innovation rich sectors of technology and industry. However, as contemporary frameworks of the Anthropocene become more widely recognized it is now evident that knowledge infrastructures are linked to planetary processes through evolution of the Technosphere (i.e., the sum of technologies produced by humans and the systems that support it²⁴⁸). Theorists argue that knowledge infrastructures, through their enmeshed institutional and environmental linkages, have the capacity to contribute to “large-scale, long-term, anthropogenic environmental change” making them essential for future planetary management.²⁴⁹ Other scholars make related claims, arguing that the dynamic interplay between knowledge infrastructure, institutions, and environmental systems operate at multiple scales, from the individual actor/organization to vast territorial networks.²⁵⁰ Today we may look towards these systems of information and knowledge exchange as infrastructure to support both the advancement of human endeavors and agents of change in planetary systems.

Linkages between knowledge infrastructure and the earth’s atmospheric, hydrologic, and geologic systems are readily observable in fields of climate science and agriculture, but also within the allied fields of environmental design, planning, and engineering through the use and production of spatial data and science. Geographical knowledge infrastructure, such as Geographical Information Systems (GIS), are regularly utilized in practice and pedagogy to spatialize data and develop core technologies such as those integrated with smart cities. Collectively these geographical knowledge infrastructures have the capacity to alter the built environment through territorial intelligence.²⁵¹ This form of knowledge infrastructure spatializes geographical data to effectively plan, design, and analyze the built and natural environment,

²⁴⁷ Laurens Klerkx and Cees Leeuwis, “Balancing Multiple Interests: Embedding Innovation Intermediation in the Agricultural Knowledge Infrastructure,” *Technovation* 28, no. 6 (2008): 364–78.

²⁴⁸ “The Unbearable Burden of the Technosphere,” UNESCO, March 27, 2018, <https://en.unesco.org/courier/2018-2/unbearable-burden-technosphere>.

²⁴⁹ Edwards, “Knowledge Infrastructures for the Anthropocene.”

²⁵⁰ Moulaert and Hamdouch, “New Views of Innovation Systems: Agents, Rationales, Networks and Spatial Scales in the Knowledge Infrastructure.”

²⁵¹ Robert Laurini, *Geographic Knowledge Infrastructure: Applications to Territorial Intelligence and Smart Cities* (Elsevier, 2017).

making the data sets, tools, and actors integral to planetary management. And although verging on the technocratic, access to this geographical data is important not only to professional praxis but to the creation of an informed public through knowledge ‘discovery’ interfaces that support interaction and engagement with large datasets that empower decision makers at local levels across a range of geographies and cultural contexts.²⁵²

Looking towards a future in which urbanized and managed coastal systems become more technologically advanced, networked, mapped, sensed, and ecologically integrated, a coordinated strategy is required ground innovation in the range of works undertaken in the coastal adaptation and resilience problem space. Addressing issues of technological capacity within emergent sectors, the Y02A patent classification scheme covering the “technologies for adaptation to climate change” aims to focus the core capacities of the patent systems on the global challenges of a changing planet – building the essential knowledge infrastructure for innovations in related climate adaption sectors including coastal adaptation and resilience. Details of the Y02A scheme are fully discussed in the following chapter (chapter 6), however it is important to note here that the scheme aims to coordinate patent data, facilitate dissemination of technical information, hasten technology transfer, and operationalize the knowledge infrastructure of the patent system in climate adaptation efforts. With regards to the core functions of search, citation, and classification, the Y02A consolidates and organizes the cross-sectoral technologies required to address climate change, making searches more accessible and creating new classifications of technology – including green infrastructure, water systems, and coastal technologies.²⁵³ Obviously, the technical information communicated via patents is highly specific to the representational conventions and legalese of the patent system in which drawings and text are akin to invention, raising important questions about the viability of new technology whilst unlocking the possibility of projecting future imaginaries through visual representation.

²⁵² Inya Nlenanya, “Building an Environmental GIS Knowledge Infrastructure,” in *Data Mining Applications for Empowering Knowledge Societies* (IGI Global, 2009), 260–77; “Water Atlas,” ArcGIS StoryMaps, April 14, 2020, <https://storymaps.arcgis.com/stories/808093e2f9ce402db1a837027ca05a5e>.

²⁵³ “CPC Scheme - Y02A TECHNOLOGIES FOR ADAPTATION TO CLIMATE CHANGE,” accessed May 9, 2023, <https://www.uspto.gov/web/patents/classification/cpc/html/cpc-Y02A.html>.

Representing Technology

Technical information is communicated in patent documents through text and image. This fact facilitates the projection of new technology and calls into question the nature of invention as often the representation of technology often precedes its “tangible” existence. This epistemological loophole in the inventive process is important to consider as it simultaneously hastens the rate of invention but may lead to issues, including misinterpretation and manipulation of the process. Representation of technology is central to modern patent rights, which is founded on the theory that drawings, and text, can be sufficient to describe the scope and functioning of an invention. Central to this issue is the term “reduction to practice” which is a step in the inventive process in beyond the initial conception when either an invention is shown to work or a patent application with sufficient disclosure is submitted. In essence this means that the drawings, models, and textual description are akin to invention as they should describe the proper functioning of the invention.

A patent is, in essence, a textualized and visualized representation of an invention, operating simultaneously as a legal document disclosing the nature of an invention and projection of a future potentiality. Modern representational standards for patents originated in the United States and later France in the latter part of the eighteenth century – requiring drawings and models of novel inventions.²⁵⁴ The US Patent Act of 1790 states that grantees shall deliver to the Secretary of State, Secretary of War, and Attorney General “a specification in writing, containing a description, accompanied with drafts or models, and explanations and models (if the nature of the invention or discovery will admit of a model) of the thing or things, by him or them, invented or discovered.”²⁵⁵ Through this representational mechanism inventors coevolved the technological substrate of “the arts” towards unforeseen ends through future projections and representation of innovative technology.

Today drawings are now universally included in patent applications, when necessary, to effectively communicate the details of a specific invention. These drawings, along with textual claims, descriptions, and citations, are later published and searchable, facilitating the diffusion of

²⁵⁴ Biagioli, “Patent Republic: Representing Inventions, Constructing Rights and Authors.”

²⁵⁵ US Government, “United States Patent Act” (1790).

innovation and the communication of technical information. The value of patent drawings is manifold, serving to effectively describe new inventions and simultaneously in the communication of technical knowledge and creation a visual repository to inform future inventions. As Eugene Furfeson argues in “Engineering and the Mind’s Eye,” representations of technology are fundamental to the development and dissemination of technical knowledge, reminding us that Edison’s inventions were first sketches before prototypes – operating like

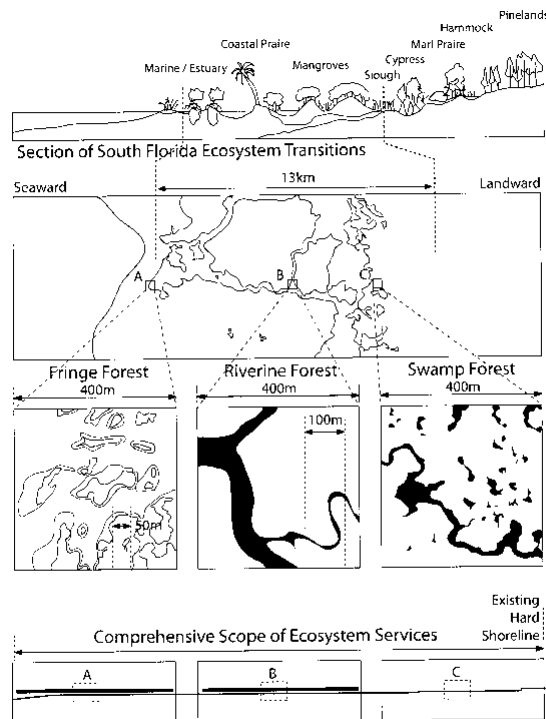


FIG. 4

Figure 26: US8511936B2 “Method and apparatus for coastline remediation, energy generation, and vegetation support” includes maps and ecological data to situate the technology in context (2013). (Source: European Patent Office, <https://www.epo.org/en>)

Edison’s automatic printing telegraph to directly communicate information between image and eye. This complex process of representing and communicating technical information involves not only the interpretation of data, text, and equations but also the visual communication of ideas from which new ideas and technologies can be developed.²⁵⁶ In the context of the patent system, text and image are used to disclose the nature of invention, helping to describe a new technologies scope and application while contributing primary information to the larger knowledge infrastructure of the patent system as it build upon sequential innovations disclosed in drawings and text.

Conventional patent drawings, include plan, section, elevation, axonometric, and diagrams, drafted in black and white line and labelled to correspond to textual description in patent claims. Critics argue that drawings of patented technology using patent conventions of technical drawing (I.e. Plan, section, axonometric, diagram, etc.) are deterministic in the types of technology that can be invented, leading to a kind

²⁵⁶ Eugene S. Ferguson, *Engineering and the Mind’s Eye* (Cambridge, Mass.: MIT Press, 1993).

of banal standardization biased towards mechanized inventions and industrial production.²⁵⁷ Yet many inventions aim to operate in domains beyond the mechanical and industrial with innovative approaches to the contingencies of site and geography. Briefly consider a recent patent by Keith Van de Riet, Jason Vollen, and Anna Dyson known as a US8511936B2 “Method and apparatus for coastline remediation, energy generation, and vegetation support”, also mentioned in chapter 4, which includes technical specifications and mappings that show the ecological extents of the invention.²⁵⁸ (figure 26)

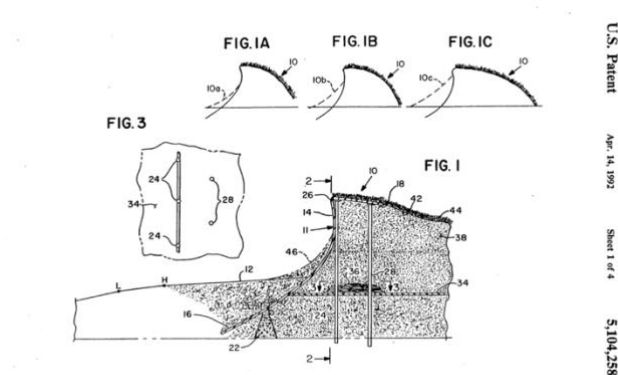


Figure 27: “Bionic dune” US 5104258 (1992) showing technical details of a self-building dune construction system. This invention is now in the public domain and can be freely used and manufactured. (Source: European Patent Office, <https://www.epo.org/en>).

Numerous technologies and forms of infrastructure converge in coastal zones, and as such coastal technologies have a long history of visual representation in patent documents. These drawings can be invaluable for the communication of technical and environmental knowledge, helping to build robust historiographies and to project future imaginaries. Within the context of coastal adaptation and resilience planning, a vast visual and technical repository exists within the patent archive

for the technologies to structure, build, sense, and design adaptive and resilient coastal systems. Since no “construction manual” or “guidebook” exists for adapting coastal systems to climate change, this evolving knowledge infrastructure can serve both heuristically to help problem solve and as a technological database to develop frameworks for innovation. Practitioners and theoreticians can interpret, build upon, debate, or advance these, and early technologies as they build context for future discoveries or technical details. For example drawings of Allan W. Ianall’s “Bionic dune” US 5,104,258 (1992) describes the structure and configuration of a dune system

²⁵⁷ Rankin, William, “The ‘Person Skilled in the Art’ Is Really Quite Conventional: US Patent Drawings and the Persona of the Inventor, 1870–2005,” in *Making and Unmaking Intellectual Property: Creative Production in Legal and Cultural Perspective*, eds., Mario Biagioli and Peter Jaszi (Chicago, IL: University of Chicago Press, 2015).

²⁵⁸ Van de Riet, K, J Vollen, and A Dyson. 2013. “Method and Apparatus for Coastline Remediation, Energy Generation, and Vegetation Support,” US8511936.

designed to turn back sands and waters – offering a novel strategy for self-actuating dune restoration.²⁵⁹ (Figure 27) The patent includes useful construction details and technical specifications. Importantly, many technologies, such as the bionic dune, are now in the public domain and can be freely produced and replicated by anyone.

Translating Patent Knowledge Infrastructure into Coastal Infrastructure: A case study from the Resilience by Design Bay Area Challenge

In 2017 the Resilience By Design Bay Area Challenge was launched in California, with ten international and multidisciplinary teams selected to develop strategies for sea level rise and climate change adaptation in the region. The “Common Ground” Team, led By Tom Leader Landscape Architects, used patent data and innovation studies, coupled with a heuristic process, to develop innovative strategies for coastal and resilience. Translations between patent knowledge infrastructure and coastal planning processes leverage the vast repository of technical knowledge archived by the global patent system to help problem solve and invent contemporary solutions emerging in the coastal adaptation and resilience. This approach to utilizing patent knowledge infrastructure to conceptualize new forms of coastal infrastructure was tested as part of the Resilience By Design Bay Area Challenge, thus establishing a framework for integrating sociotechnical aspect of innovation into localized site-strategies.

Background and Structure of the Resilience By Design Bay Area Challenge

Resilient by Design “Bay Area Challenge” was modeled on New York “Rebuild by Design”, bringing together residents, public officials, and local, national, and international experts to develop innovative community-based solutions to strengthen the Bay Area’s resilience to sea level rise, severe storms, flooding, and earthquakes. The Challenge was funded by the Rockefeller Foundation in partnership with the U.S. Department of Housing and Urban Development and supported by a range of local institutions and community partners.

²⁵⁹ Allan W. Ianell, Bionic dunes, US5104258A, filed June 21, 1991, and issued April 14, 1992.

Organizationally, the program dovetailed with the Rockefeller Foundation's 100 Resilient Cities network, which aims to build social and technical infrastructure for climate adaptation and resilience in cities around the world.

The year-long Resilient by Design Bay Area Challenge is a collaborative design challenge located in the Bay Area of California. It contributed to specific resilience planning in San Francisco, Oakland, and Berkeley, through their involvement with the 100 Resilient Cities program and built capacities for greater regional collaboration to address climate adaptation with sites around the bay area region, including the San Pablo Baylands and southern extents of the bay near Palo Alto and Silicon Valley. The vast geography of the Bay Area presents a distinct planning challenge, as the shoreline crosses hundreds of jurisdictions and countless communities sharing, making coordinated planning efforts a challenge to implement. In response to this dynamic context, sites were assessed and later distributed around the region, with teams composed of design leads, consultants, and community groups in collaboration with local stakeholders.

The Bay Area Challenge launched on May 31, 2017, with an open call for Design Teams to participate and an open request for site suggestions within the regions. Over 50 teams from around the world applied to enter and 10 teams were selected to advance to the research phase. The research phase involved site evaluation and initial focused research on subjects germane to site selection such as subsidence, social justice, and transportation, etc. This process helped to scale and scope project types and geographical regions of interest. The design teams included firms such as AECOM, BIG, Bionic, TLS, Field Operations, Mithun, Base Landscape, SCAPE, Gensler, who guided team selection, site selection, and all phases of stakeholder collaboration in dialogue with the program management team and design jury.

The Collaborative Design phase (i.e. final design phase) kicked off in January 2018, with community meetings and the formation of local advisory groups in each project area. Nine projects and teams advanced through the year-long process, including Elevate San Rafael (Bionic), Unlock Alameda Creek (Public Sediment), The Peoples Plan (P+SET), South Bay Sponge (Field Operations Team), Estuary Commons (ABC), The Grand Bayway (Common Ground), Connect and Collect (Hassell+), ouR-Home (Home Team), Islais Hyper-Creek

(BIG+ONE+Sherwood). In essence each design team develop innovative design proposals for their final sites, including frameworks for research, social engagement, and implementation, etc. The competition, now completed, is extensively documented on the Resilience By Design Bay Area Challenge website and as part of a limited circulation publication that offer a comprehensive overview of the process and outcomes.²⁶⁰

Site, Team, and Project Narrative

The Common Ground Team selected the San Pablo Baylands, and its adjacent infrastructure and urban fabric as a site. The Common Ground Team was comprised of landscape architects, urban designers, architects, scientists, artists, educators, economists, community organizers, academics, ecologists, and civil, hydrological, geotechnical, and structural engineers. The team was led by Tom Leader (TLS) landscape architecture, and team members included in the San Francisco Exploratorium, Guy Nordenson and associate, Michael Maltzan architecture, Sitelab urban studio, HR&A Advisors, Lotus Water, Rana Creek Design, Dr. John Oliver, Richard Hindle (author), Fehr & Peers.



Figure 28: Site location and context - San Pablo Baylands, State Route 37, and Sea Level rise (Image credit: TLS & "Common Ground" Team, 2017-2018)

The site selected by the team was the San Pablo Baylands marsh west of Vallejo, California, and State Route 37. A major component of the project was a restoration of the highly degraded, channelized, and subsided wetland now operating as agriculture, bound by levees, and traversed by California State Route 37 (figure 28). The heterogenous nature of the site presented distinct challenges, including how to reclaim the agricultural lands that are now below sea level due to subsidence. The mosaic of

²⁶⁰ "Bay Area: Resilient By Design Challenge," Bay Area: Resilient By Design Challenge, accessed June 21, 2021, <http://www.resilientbayarea.org>.

agricultural lands reveals acute problems with the site's topography, with some areas now transitioning to open water through levee breaches, and others remain actively cultivated.

State Route 37 was identified as a major issue, leading to the proposed Grand Bayway causeway. The road now exists as a low-lying commuter route that skirts the northern edge of San Pablo Bay, where it is simultaneously traffic-choked and increasingly flood prone due to sea level rise. The highway structure is situated on a precarious 'ballast' levee that confines an immense marsh complex at the interface of the Napa River, several creeks, and the San Pablo Bay situated between Carquinez Strait and the San Francisco Bay. The core of the site contains two large zones with distinct marsh ecosystems associated with the estuary of the Napa River and the San Pablo Bay – a complex coastal ecology known as the San Pablo Baylands. Historically, the western baylands were farmed and the eastern baylands that were used for salt ponds. Today cattle grazing and agriculture is still active, though there is an effort towards restoration with



Figure 29: design vision for the "Grand Bayway", replacing state route 37. (Image credit: TLS & "Common Ground" Team, 2018)

limited success. The large portion of the site that was farmed for over 100 years lost much of the peat in the soil and had no input of sediment during that time, resulting in areas of land subsidence up to 7 feet. Restoring these areas by conventional means would consume a huge amount of resources so innovative strategies and novel approaches are essential to a future vision.

The team developed a multifaceted approach to the site and a framework for the "Grand Bayway". The proposal aims to resolve the transportation problem of Highway 37 by designing a scenic elevated causeway that allows tidal flows and natural marsh migration to return to a natural condition. The causeway was designed with other iconic bay area crossings in

mind, with expanded consideration for the natural environment and multimodal transit types. Principles of scenic byway design, curving to open views over the Bay and marshes and oriented to natural landmarks. The proposal established a new entryway to the San Francisco Bay Area. The team branded the project as an ecological “Central Park” for the region, as it aims to create value for the region, its identity, and its future. A grand mobility loop was proposed to encompass the open space involving pedestrian and bike routes collocated with an excursion train using an existing freight line. Importantly, the huge bay lands complex is inextricably linked to the resolution of the highway and the team invested considerable time developing strategies for this complex coastal landscape.

Building a Technical Dossier - The Patent System as Knowledge infrastructure for site design technologies

The core capacities of the patent system include a range of search, metadata, citation networks, language translation, image, and ever evolving classification systems serve as vital knowledge infrastructure for all sectors of innovation, including coastal adaptation and resilience. The importance of this innovation knowledge infrastructure is the subject of debate. However, it may be understood as serving not only the goals of industry, but also broader societal goals effective use of innovation and dissemination of knowledge. For example, the World Intellectual Property Organization (WIPO), a specialized agency of the United Nations located in Geneva, Switzerland, promotes “development of a balanced and effective international intellectual property system that enables innovation and creativity for the benefit of all.”²⁶¹ In service of this mission, the WIPO utilizes the knowledge infrastructure of the patent system to advance strategic initiatives such as linking innovation to issues of global development and policy.²⁶² Of course, the innovation knowledge infrastructure not only has tangible implication for management of sequential innovation and global development issues, the systems also has the capacity to facilitate discovery, share knowledge, and providing

²⁶¹ “World Intellectual Property Organization,” accessed June 14, 2023, <https://www.uspto.gov/ip-policy/patent-policy/world-intellectual-property-organization>.

²⁶² Yo Takagi, “WIPO’s New Strategies on Global Intellectual Property Infrastructure,” *World Patent Information* 32, no. 3 (2010): 221–28.

information that may be utilized and translated in legal, technical, and non-technical domains alike – including coastal adaptation and resilience sectors.

Patent documents, and their metadata, are widely used by inventors, companies, and scholars to construct innovation studies, define areas of innovation, and build upon technological trajectories in a range of technology sectors. For example, in the field of patent informatics patent data is used for predictive and analytical research forecasting trends in technological innovation, policy, economics, and society.²⁶³ Individual corporations may also use patent data to help understand a business's capabilities, relationship to others in the industry, and to establish technological positions within a sector.²⁶⁴ Patent data research relies on a wide range of research methods, including big-data 'scraping' to discover macro trends to detailed analysis of specific patented technologies. Together the data and detailed information of specific patented technologies represent one of the world's largest repositories of technical information that can be interpreted and translated in technical, and non-technical domains alike through the core functions of the global patent system is the capacity of search, citation, and classification of technology.

In the specific case of the 2017 Resilience By Design Bay Area Challenge, the Common Ground team utilized technical information from individual patents and analysis of their associated groupings, to develop a coastal adaptation and resilience strategy. Three types of publicly accessible searches were used during this process, including classification searches, citation searches, and keyword searches. This allowed the team to rapidly gain knowledge about the innovation landscapes related to the project and build upon established technologies, such as the site-integrated "sediment train" which advanced ideas disclosed in US1980634 "Method of Building Levees" (1932/34).²⁶⁵ The system, now in the public domain, utilized railroad tracks and dragline excavators to coordinate levee construction and sediment management – serving

²⁶³ Assad Abbas, Limin Zhang, and Samee U Khan, "A Literature Review on the State-of-the-Art in Patent Analysis," *World Patent Information* 37 (2014): 3–13; Ben Buchanan, "Unlocking the Value of Patent Data: Patent Informatics Services at the UK Intellectual Property Office (UK-IPO)," *World Patent Information* 30, no. 4 (2008): 335–37; Juite Wang and Yi-Jing Chen, "A Novelty Detection Patent Mining Approach for Analyzing Technological Opportunities," *Advanced Engineering Informatics* 42 (2019): 100941.

²⁶⁴ Shann-Bin Chang, "Using Patent Analysis to Establish Technological Position: Two Different Strategic Approaches," *Technological Forecasting and Social Change* 79, no. 1 (2012): 3–15.

²⁶⁵ William E. Philips, Method for building levees, US1980634A, filed November 14, 1932, and issued November 13, 1934.

as a precedent for a similar system as part of the site plan (figure 30).

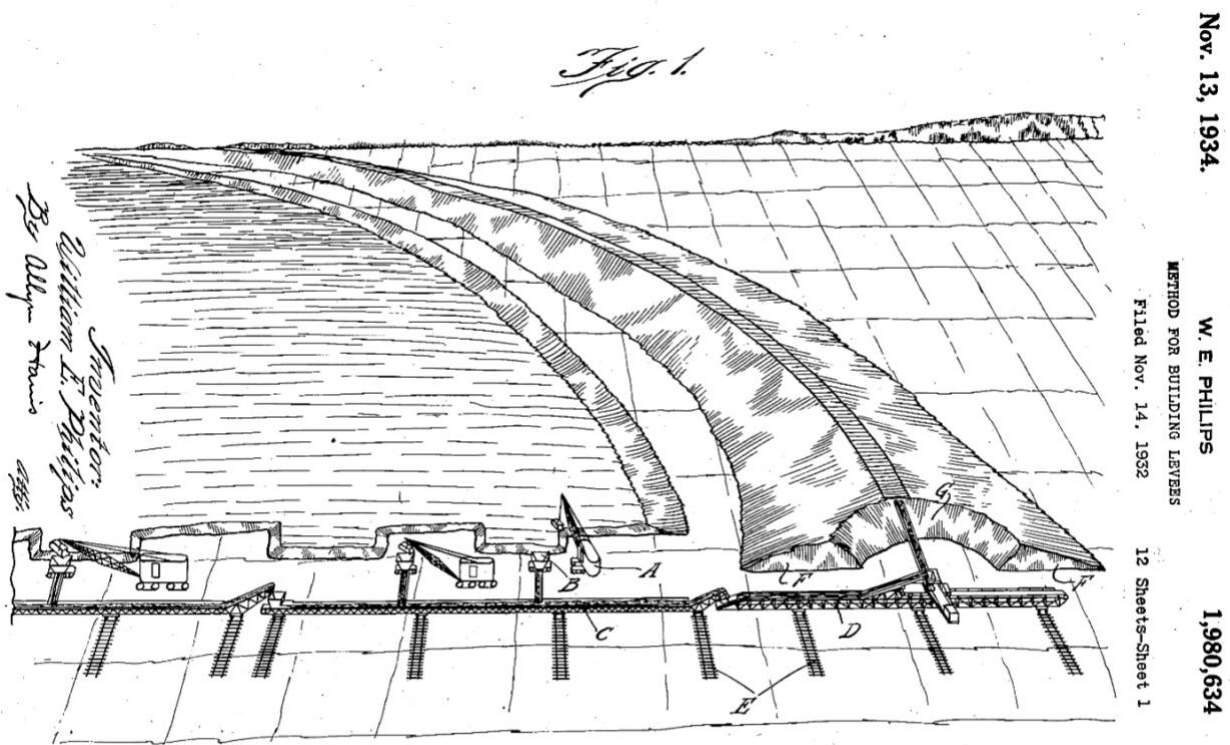


Figure 30: Drawing from US1980634 “Method for Building Levees” which provided technical information and conceptual precedent for the “sediment train” proposed by the Common Ground Team for use in deltaic restoration. (Source: European Patent Office, <https://www.epo.org/en>)

Citation networks essentially link prior art, and future inventions, using citations. Just as in scientific literature, patents include citations of prior art and non-patent citations to ensure the claims made by the patent are novel and constitute a substantively new contribution. Citation networks provide an important window into specific sectors of technology. Citation searches are among the simplest to conduct as bibliographic data is associated with each patent for citations and future reference to each patent. Accessing this information is simple through free online searches, and the data acquired in this manner can also be used to construct more robust network mappings or serve as the basis for advanced research in a specific sector. For example, recent publications on innovation in the building sector used patent citations as the primary method, concluding advances in computer, communication technology in the industry

and recommend incentives for energy technology.²⁶⁶ Google patents, the USPTO, and European Patent office, can all be used to construct citations networks that situate individual patents within a context of prior art and evaluate their relationship to future inventions. They can

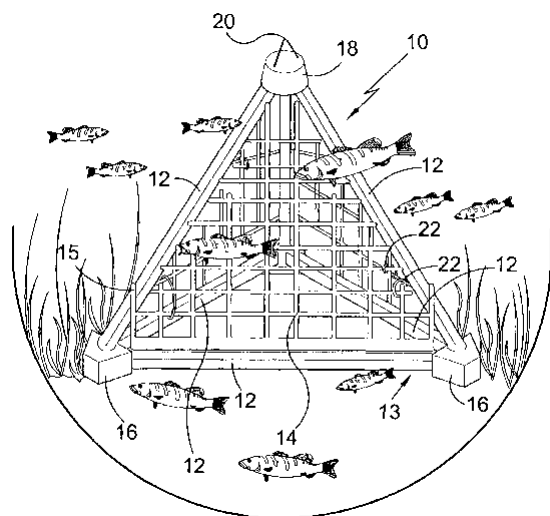


Figure 31: US 6824327 for an "Artificial Barrier Reef"
(Source: European Patent Office,
<https://www.epo.org/en>)

expand the notion of a singular invention and suggest areas for further research. Importantly they provide context for design interpretation through recognition of prior-art. Citations searches helped the Common Ground Team identify a suite of leading edge artificial reef technologies for inclusion in the San Pablo Baylands Scheme and also to the creation of a living "benthic lab" to test and evaluate new ecological technologies such as US6824327 for an "Artificial Barrier Reef" and the citation web of 33 past, and present, inventions included in its references (figure 31).²⁶⁷

Linkages between inventions are made through citations, just as ideas are cited in scholarly literature. Citation of prior-art and patent classification are fundamental to the patent system, creating networks of related technologies to prove novelty and also situate a patented technology in context. These citations may be mapped to create citation networks and are valuable in innovation studies within and outside technological fields. For example, the metadata associated with a patent and its citation network may be used to not only to model innovation but to comprehend complex relations between urban planning and innovation.²⁶⁸

Keyword Searches provide another robust search tool within patent search databases. When coupled with customized date ranges, and issuing patent office criteria, assignee, and other meta-data keyword searches can provide a window into the innovation landscape associated with particular types of technology. In simple terms, keyword searches function like

²⁶⁶ Joy E Altwies and Gregory F Nemet, "Innovation in the US Building Sector: An Assessment of Patent Citations in Building Energy Control Technology," *Energy Policy* 52 (2013): 819–31.

²⁶⁷ David M. Walter, Artificial barrier reef, United States US6824327B1, filed May 27, 2003, and issued November 30, 2004

²⁶⁸ Jung Won Sonn and Michael Storper, "The Increasing Importance of Geographical Proximity in Knowledge Production: An Analysis of US Patent Citations, 1975–1997," *Environment and Planning A* 40 (2008): 1020–39.

other web searches allowing searchers to find specific documents, assess the relative frequency occurrence of a particular term, or gain knowledge about its relative scarcity within the assigned search criteria. This intuitive type of patent search is invaluable as a starting point for research, but also can be generative for more complex innovation studies. For example, researchers use keyword search networks to map sectors of technology and evaluate amount of patent innovation occurring in specific sectors. Importantly this approach can also be used to identify areas in which patent innovation is lacking, therefore suggesting areas of technology where new investment, research, and development may be warranted.²⁶⁹ The mining of patent text also yields interesting insights about technology, with new tools available for analysis of massive textual data sets.²⁷⁰ During the technical assessment phase of the Resilience By Design

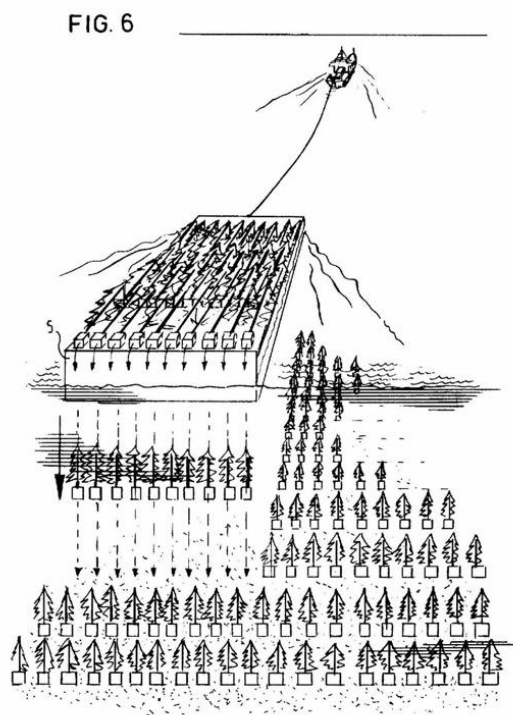


Figure 32: US4397587 “Method Of Constructing An Artificial Island And Island Constructed By The Same” (1980). Showing the process of arraying trees to form and island. (Source: European Patent Office, <https://www.epo.org/en>)

competition the Common Ground Team used keyword patent searches as a form of net casting, allowing them to build patent portfolios for initial concept for artificial island building and the creation of floating wetlands. This included initial evaluation of speculative technologies such as US4397587 “Method Of Constructing An Artificial Island And Island Constructed By The Same” which utilized a vast matrix of vegetation and sediment to build ground (figure 32).²⁷¹

²⁶⁹ Sungjoo Lee, Byungun Yoon, and Yongtae Park, “An Approach to Discovering New Technology Opportunities: Keyword-Based Patent Map Approach,” *Technovation* 29, no. 6–7 (2009): 481–97.

²⁷⁰ YunYun Yang et al., “Text Mining and Visualization Tools—Impressions of Emerging Capabilities,” *World Patent Information* 30, no. 4 (2008): 280–93.

²⁷¹ Den Velde Jan Op, Jan B. Elzerman, and Klaas Oterdoom, Method of constructing an artificial island and island constructed by the same, US4397587A, filed October 6, 1980, and issued August 9, 1983.

Patent classification searches may also provide insights about technological trends. Patent classification systems have evolved over time to group and organize patented inventions by sector. For example, the United States Patent Classification (USPC) initially contain 16 classes of technology in 1836 and by 2014 more than 430 classes were created to keep pace with technological innovation.²⁷² Patent classification is a system of sorting inventions and their documents into technical fields covering all areas of technology, including areas of new technology that are not yet classified. By organizing patent by classification, each document can be found based on sector as well as through keywords, etc., facilitating searches and insights about technological concepts and their relationships.²⁷³ Benefits of patent classification systems make it easier to file and retrieve patent documents, and also to look back in time to find antecedents of technology. These classification searches played a central role in building the technical dossier as part of the Common Ground team, particularly in areas of arcane knowledge such as plashing (i.e. structurally woven hedge/fences) which were used by the design team to delineate boundaries and capture sediment in “accretion gardens,” unearthing technical details and drawings such as those describing US380450A for “Hedge” (1888).²⁷⁴ Today the Y02A classification scheme aims to reorganize patent classifications searches for the “technologies of climate adaptation” making the searches for related technologies more accessible and efficient.

Methods – Design Heuristics and Technical Specifications from Patents

The research and design development stages of the project utilized patent innovation mapping to establish a baseline understating of the technological landscape associated with the core issues facing the site – namely the challenge of a sediment deficit and a dearth of time to prepare land for sea level rise. The team focused research on finding more innovative ways to build land in the bay lands and create a resilience coastal ecosystem, this included budgeting existing sediment resources to greatest effect, designing ways to redirect sediment in flood

²⁷² Simmons, “Categorizing the Useful Arts: Part, Present, and Future Development of Patent Classification in the United States.”

²⁷³ Tiziano Montecchi, Davide Russo, and Ying Liu, “Searching in Cooperative Patent Classification: Comparison between Keyword and Concept-Based Search,” *Advanced Engineering Informatics* 27, no. 3 (2013): 335–45.

²⁷⁴ Mitchell James, Hedge, US380450, filed 1888, and issued April 3, 1888.

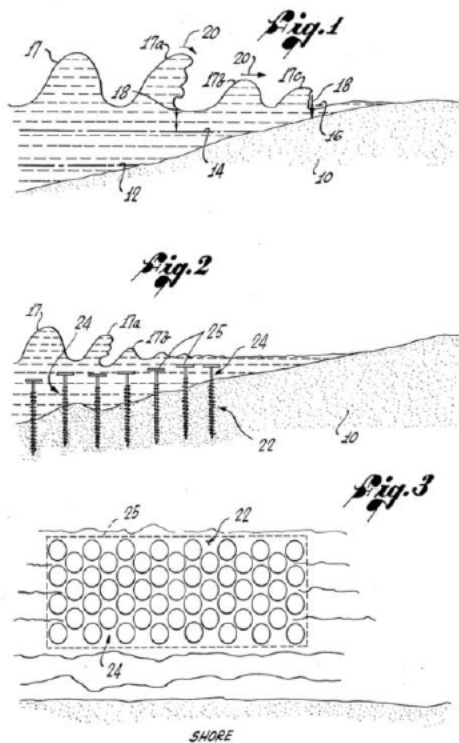


Figure 33: US4006598 "Breakwater System" - an example of patents included in the technical dossier for specific site technologies. (Source: European Patent Office, <https://www.epo.org/en>)

events, direct sediment through both natural and artificial processes to existing marshes and future retreat zones, the control of water, and establishment of artificial ecologies on the site.

Instead of providing fixed masterplan and rigid infrastructure for the 50,000-acre site (20,234 hectares), the contingencies and phasing of the site strategies were linked to specific site timelines and relevant technologies for accretion of sediment, benthic ecology, water regulation, and incremental adaptations to sea level rise. Each landscape condition was the linked to an innovation dossier of patented technologies that might be used to structure the site. In certain instances, specific site assemblies were suggested, and integrated into the design, showing how each technology would impact the site and future scenarios for the region.

The team adapted existing technologies to the design framework, and then made informed suggestions for future needs based on these innovation studies. For example, concepts such as "permeable dikes" were developed through patent research and design iteration, translating details from patents such as US4006598 "Breakwater System" into site strategies for structures that allowed for the flow of water while armoring site elements and building ground at the wave impacted foreshore (Figure 33).²⁷⁵ Collectively This led to novel site designs at detail and regional scales, while linking geographical contingencies to technology. The knowledge infrastructure provided by patent archives and technical specifications were integral to the process, including patent drawings and technical specifications.

²⁷⁵ Jobst Hulsemann, Breakwater system, US4006598A, filed November 24, 1975, and issued February 8, 1977.

In the initial net-casting phase of the design process an extensive list of possible strategies emerged through discussion and design iteration. As ideas were posited by the team specific language, sketches, and precedent images were compiled into 26 final categories, including descriptions. The concepts, keywords, and drawings, compiled during this process were used to conduct patent searches. keyword, classification, and citation network searches were conducted and from this a visual and textual dossier of “prior-art” was created to facilitate the creative ongoing process and was winnowed through discussion and revision to include a wide array of related technologies. This net-casting involved a range of subject categories for conceptual development, including Channel Chamfers, Plashed Hedgerows, Structural Sediment Accumulators, Water Gates, Biomass Farming, Carbon Sequestration (soils), Micro-topographies, Sediment Train, Artificial Seaweeds, Benthic habitat / Artificial Reefs, Artificial Islands, Groundwater Recharge, and Mollusk Habitat, etc. (Figure 34 & Table 4).

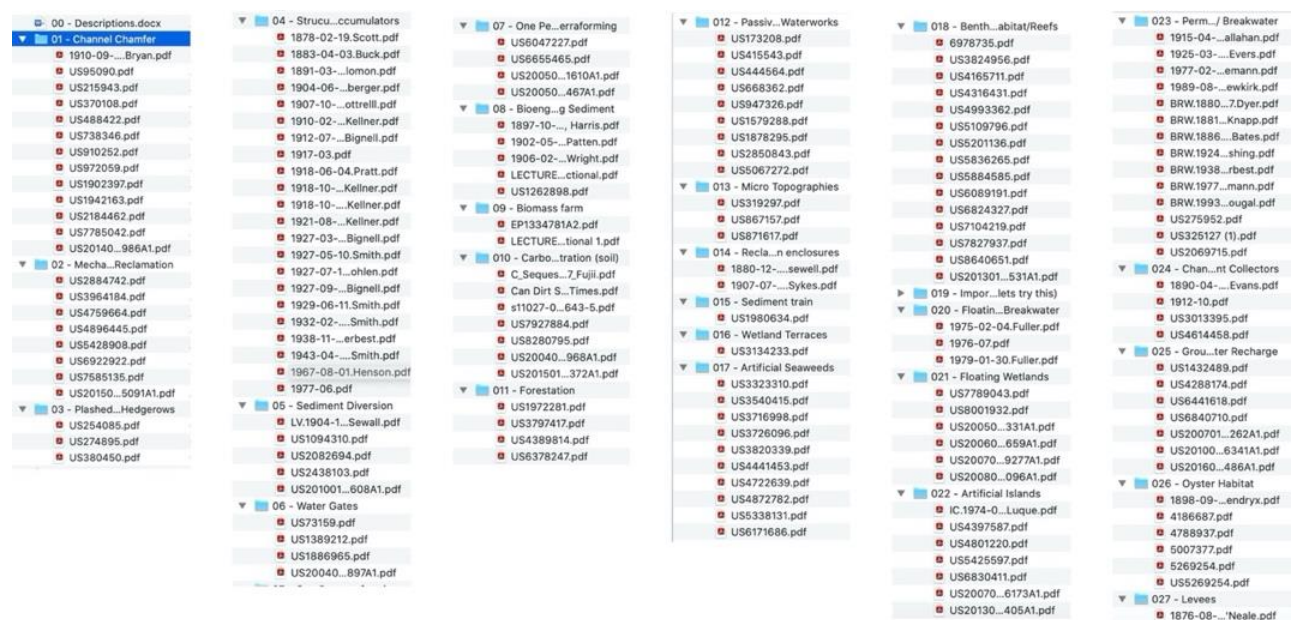


Figure 34: Patent Dossier (Text/Image) for use by the design team (Source: TLS & "Common Ground" Team, 2017-2018)

The patents related to each category functioned as carriers of innovation that create context for innovation and help define technical domains during the design process. In this context patent archiving and collating creates a heuristic from which inventors may borrow,

adapt, and innovate.²⁷⁶ Heuristics can become an essential method to defining new technologies or for strategic design thinking. In the field of engineering design heuristics are often used to help generate new concepts through sketching and other forms of ideation.²⁷⁷ Similarly, in the fields of industrial and product design heuristic methods utilizing existing product knowledge and datasets facilitate the creation of innovative new solutions to fundamental design problems.²⁷⁸ Beyond the envisioning and net-casting heuristic process, the patent innovation studies also provided technical specifications and details associated with specific coastal infrastructure, such as artificial benthic ecology and floating wetlands. These technical specifications reveal the value of patent knowledge infrastructure for the diffusion of innovation.

Living Lab - Innovation as Infrastructure

The team envision the San Pablo Baylands as a territory in process – a national experiment at the cutting edge of reclamation and adaptation to sea level rise. To accomplish this vision the team proposes a planning framework that embraces experimentation, and works to solve complex issues related to subsidence, sea level rise, and ecological degradation. The site therefore is structured as a series of experimental reclamation sites that borrow from historical precedents and leading-edge technology. The research phase involved the development of coastal landscape technologies that addressed issues related to the site. These typologies were developed during collaborative team meetings involving a range of experts, including ecologist, technologist, planners, and designers.

Central to this concept was the “living lab” as an institutional proposal for the site built on the need for ongoing innovation. A general theory of invention suggests that searching is the essential framework for discovery involving the iterative and recursive stages of stimulus, net casting, categorization, linking, and discovery.²⁷⁹ It is hypothesized that in the process of searching, inventors gather information inside and outside of their domains to create mental

²⁷⁶ Stefan Bechtold, Christopher Buccafusco, and Christopher Jon Sprigman, “Innovation Heuristics: Experiments on Sequential Creativity in Intellectual Property,” *Ind. LJ* 91 (2015): 1251.

²⁷⁷ Shanna R Daly et al., “Design Heuristics in Engineering Concept Generation,” 2012.

²⁷⁸ Seda Yilmaz et al., “Design Heuristics in Innovative Products,” *Journal of Mechanical Design* 138, no. 7 (2016).

²⁷⁹ Edwards, “Knowledge Infrastructures for the Anthropocene.”

schemas to link ideas, build context, and make new discoveries. The process of searching and knowledge of previous developments in a specific domain are vital to the process of new discoveries or creation of novel ideas. This process was built into the Bayland project to create adaptive capacity on the site to prepare for rising sea levels through establishment of a living lab within the masterplan founded on innovation. The proposal creates an ecological laboratory working strategically with streams and diked sloughs to incrementally re-engage sediment deposits and cultivate biodiversity through various means including “sediment trains,” hyper-accretion gardens, and artificial marine ecology. The strategy for deltaic restoration and management evolved through an iterative search, research, design testing, and revision process using patent innovation studies to develop strategies for coastal adaptation and resilience and aimed to integrate this working method into the site in perpetuity. The idea of a living lab and test-ground for innovative new technologies was a core principle of the overall design. In essence the goal was to link broad aspects of technological innovation to the site development, thus translating patent innovation into innovative strategies for coastal adaptation and resilience.

Innovative Site Strategies for building ground

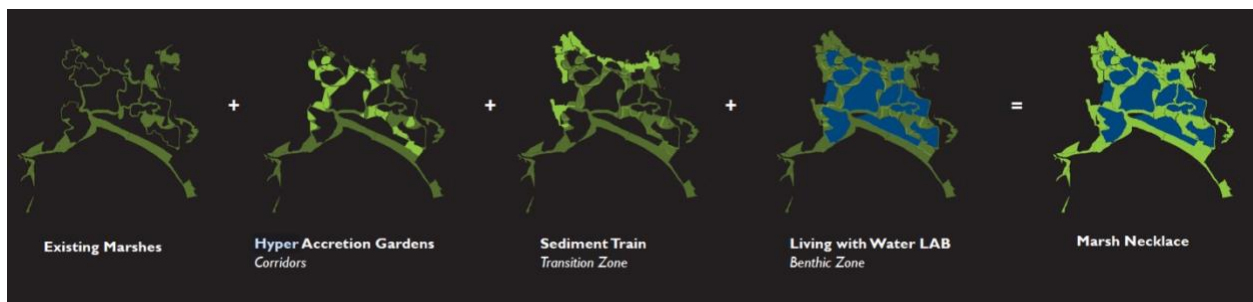


Figure 35: Site diagram showing areas of hyperaccretion, and open water based on site topography and hydrology. (Image credit: TLS & "Common Ground" Team, 2018)

Strategies for restoration and management of the San Pablo Baylands evolved from a reading of the sites natural systems, cultural history, and the heuristic process evolving from patent innovation research. This process led to an innovative landscape strategy built on the creation of hyperaccretion “gardens” along existing channels, areas of open water serving as a

marine ecology lab, and a fixed sediment train to distribute sediment sources throughout the site (figure 35). Working with land and topography as a medium of innovation was central to the project thesis, facilitating the conceptualization of a landscape mosaic with wetlands, sediment transport, and open water, that maximized site performance given the realities of sediment deficit and sea level rise. The three site strategies outlined below exemplify the dynamic interplay between technology and site, revealing how patent innovation studies were translated into site design and planning.

Hyper-Accretion Gardens

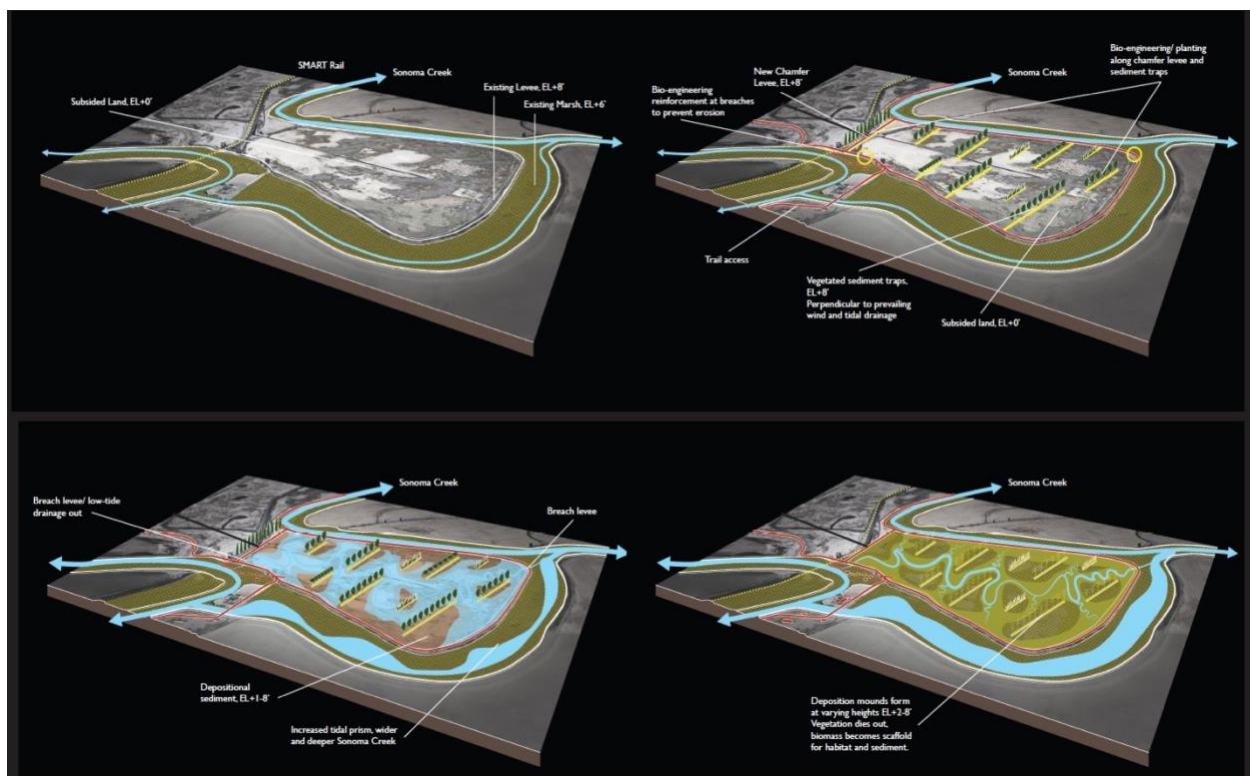


Figure 36: Diagrammatic rendering of hyperaccretion gardens located at channel bends. (Image credit: TLS & "Common Ground" Team, 2018)

Sediment capture and stabilization from naturally occurring creeks, sloughs, and waterways was essential to build and maintain ground in the Baylands. A central feature of the site strategy was modular levee breaches along elevated sloughs and waterways where sediment could accumulate at bends, or meanders in the waterway (figure 36). In principle the concept

evolved from an early 20th century patent US969334A "System to prevent the overflowing of rivers" which discloses a river with two channel flows mediated by weirs and braided channels (figure 37).²⁸⁰ The team referred to these in the masterplan as hyperaccretion gardens where sediment would accumulate at rates faster than adjacent areas. These discrete “gardens” were structured using experimental wattle fences, lattice berms, structural sediment capture devices, and water diversion, designed to accelerate natural sedimentation in both tidal and upland watersheds by “chamfers” in the channel to create new basins and channel geometry. At each potential site for hyper-accretion small, experimental, and innovate prototypes that are calibrated to various conditions throughout the Baylands, and a range of technologies were evaluated for suitability.

The Hyper-accretion gardens, located a channel chamfers, were sited in areas where they would work with land, topography, and water. Within the gardens were an array of systems, structured using novel devices from historical and contemporary patents, designed to maximize sediment accretion. This included specific subject covered by the technical dossier such as Sediment Diversions, Structural sediment accumulators, plashed hedgerows, and bioengineered sediment capture systems. The sediment diversions would be located in channels to capture bed

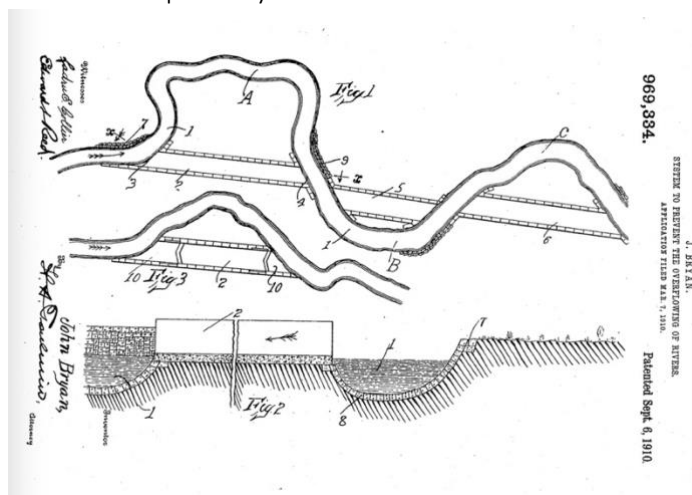


Figure 37: US969334 "System to prevent the overflowing of rivers" (1910). Conceptual and technical precedent for channel chamfers. (Source: European Patent Office, <https://www.epo.org/en>)

load, or bottom sediment, and transport it to a sediment sink in the form of an enclosure or area of sediment deficit. Structural Sediment Accumulators would be sited in a manner to aims to slow water and control currents to promote the accretion of sediments through structural geometry that modifies flow and cause turbulence. Plashed Hedgerows were integrated to the site to block wind and capture organic material within the gardens and structure the

²⁸⁰ John Bryan, System to Prevent the Overflowing of Rivers., US969334A, filed March 7, 1910, and issued September 6, 1910.

spaces by creating enclosure. And the Bioengineering Sediment Capture systems built experimental plots of living plant material to stabilize earth. When applied to the process of reclamation and reversal of subsidence, bioengineering dovetails effectively with the reuse of sediment slurries from hydrologic dredging. Bioengineered enclosures can retain sediment in a preformed geometry, allowing water to pass through fascines, woven wall, and living encloses, while retaining and stabilizing the sediment (figure 38).



Figure 38: Rendering of hyperaccretion garden showing the landscape configuration and embedded technologies. (Image credit: TLS & "Common Ground" Team, 2018)

Sediment Train

Central to the site's sediment budget was the creation of a "sediment train" to move vast quantities of material through the subsided landscape. The team determined that the greatest impediment to using dredge material to build subsided lands and nourish imperiled and eroding marshlands is the cost of transport and placement. In many places around the San Francisco Bay, the sites in need of sediment are not easily accessed. Thus, much of this material is dumped

outside of the Golden Gate Bridge via barge. In the San Pablo Baylands, the existing and underutilized rail corridor circumnavigates the marshlands at an elevation that roughly corresponds to the 100-year high water level for sea level rise, making it ideally situated for a fixed rail sediment transportation system such as that outlined in the aforementioned patent US1980634 “Method of Building Levees”, which utilized railroad tracks and dragline excavators to coordinate levee construction and sediment management. This patent, in combination with a series of integrated technologies for sediment dewatering and movement, such as US20060162195A1 “System and method of dewatering dredge spoils using sloping drain barge” served as the core systems for bulk sediment transportation (Figure 39).²⁸¹

Once the core technologies were understood, the team mapped the elevation capital for the marshes and found that the rail corridor is an excellent opportunity for future marsh and upland transition zones using the sediment sources available. Taking advantage of the intersection of the rail and navigable channel at the mouth of the Petaluma River, open-topped dump train cars would be filled with dredge spoils via barge and delivered to any place along the rail corridor. In places where the rail is near marsh habitats, sediment deposition would need to

occur in relatively small increments or “lifts”. In addition, pairing this nourishment approach with an upland transition species plant restoration would provide future high water refugia for wildlife and provide the biomass that is critical for catching the suspended tidal sediments that will eventually reach the new sediments as sea-level rises.

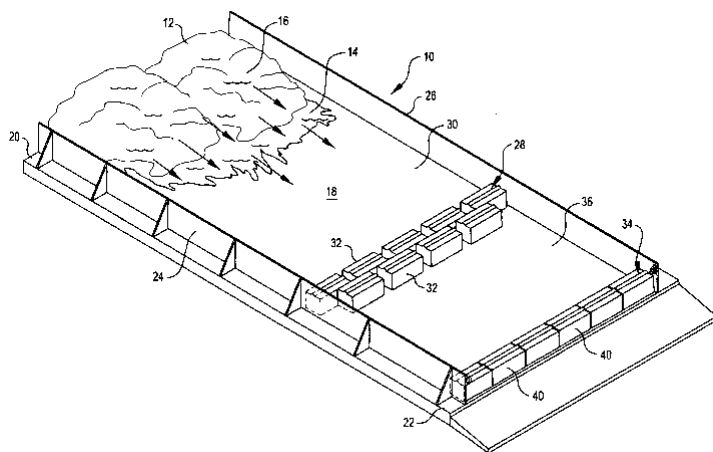


Figure 39: US20060162195A1 “System and method of dewatering dredge spoils using sloping drain barge.”(2006) Part of the project technology portfolio. (Source: European Patent Office, <https://www.epo.org/en>)

²⁸¹ Brian B. Langdon, Kenneth a Preston, and Thomas E. Coultas, System and method of dewatering dredge spoils using sloping drain barge, US2006162195A1, filed January 26, 2005, and issued July 27, 2006.

Artificial Marine Ecology and integrated Structural systems



Figure 41: Open water benthic ecology rendering, showing the landscape morphology and technologies to be used. (Image credit: TLS & "Common Ground" Team, 2018)

As sea level rises ocean/bay water will fill the Baylands in areas below sea level even though systems are in place to ameliorate this issue. The team embraced this reality, and conceptualized open water system that would armor the site and build artificial ecologies in newly formed bodies of water (figure 40). The team

proposed a series of structural interventions in the newly formed body of water, including floating breakwaters to attenuate wave suspension of mud, artificial islands, and artificial reefs in the benthic zone to rebuild ecology as the sites transition from dry to submerged habitats. Floating breakwaters would be used to increase sediment deposition and grow a shoreline as sea level rises. Artificial islands would create habitat heterogeneity and experiential interest for visitor. And the artificial reefs and habitat structures would help build new ecological communities that are essential for site colonization.

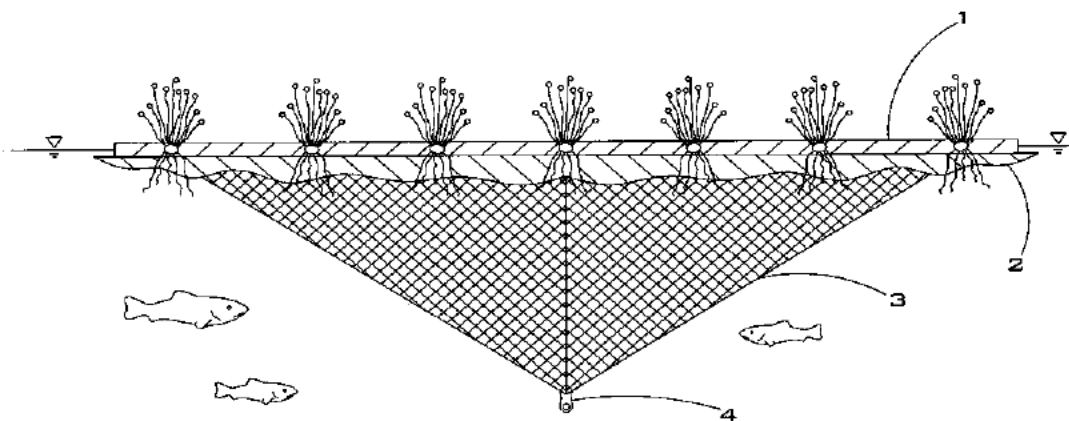


Figure 40: US20050183331A1 "Super-enhanced aquatic floating island plant habitat" – one of the many floating systems incorporated into the newly formed bodies of open water on the site. (Source: European Patent Office, <https://www.epo.org/en>)

Given the complexity of these systems it was envisioned that they would function as natural experiments that include monitoring and further revision of technologies used as part of the living laboratory. San Pablo Bay is clear natural laboratory for developing these ecological research programs embedded in human communities and activities as it is one of the most subsided and degraded sites in the Bay Area and one of the first predicted to be impacted by sea-level rise, meaning that knowledge can be gained rapidly in preparation for other analogous sites. The initial technologies implemented to build these systems would be evaluated through ongoing research, contributing to knowledge on the establishment of new ecologies in subsided landscapes. The patent dossiers for artificial reefs, artificial islands, and floating breakwaters, informed these decisions and helped establish a framework for ongoing innovation (figure 41).²⁸²

Discussion

Given the close relationship between technological innovation and the development of coastal regions the patent archive serves as a valuable dossier of visual and textual information, both historical and current, that may be interpreted and applied in the context of coastal adaptation and resilience works. Translation between the technological knowledge infrastructure of the global patent archive and the applied works planning and design presents distinct opportunities to link the sociotechnical processes of innovation to real-world project sites. The recent establishment of the Y02A has the potential to streamline this process, making knowledge about coastal innovations readily accessible and available for integration into praxis. This knowledge infrastructure can serve both heuristically to help problem solve and as a technological database to develop frameworks for innovation. During the 2017 Resilience by Design Bay Area Challenge, the Common Ground Team coupled patent-innovation studies with a heuristic process to develop innovative strategies for coastal resilience. Each landscape condition was linked to an innovation citation network of patented technologies that might structure the site. In certain instances, specific site assemblies were suggested and integrated into the design, showing how each technology would impact the site and future scenarios for the region.

²⁸² Bruce G. Kania et al., Super-enhanced aquatic floating island plant habitat, US2005183331A1, filed July 1, 2004, and issued August 25, 2005.

Patents are often translated in the humanities, design, and in other non-technical domains to develop broader narratives about law, society, history, and environment.²⁸³ Similarly within design disciplines, patent drawings and images can help track the evolution of designs and develop strategies for innovative works in a particular field.²⁸⁴ These translations have different outcomes depending on disciplinary scope and epistemology leading to varied forms of scholarship and creative works. Within the allied fields of environmental design and planning this knowledge infrastructure has the potential to inform site-strategies for coastal adaptation and resilience, helping to build on sequential innovation. As a form of innovation-knowledge infrastructure, the patent archive is essential in tracking progress in technical fields. It chronicles developments and establishes a precedent of prior art, archiving specifications, claims, and drawings while providing metadata for research, interpretation, and discovery. In emergent sectors such as coastal adaptation and resilience, this combinatory process is precious, contributing technical specifications, visual references, and future imaginaries to complex problems with planetary scope.

Table 4: Initial "Net Casting" categories used to initiate prior-art searches and built a patent dossier. (Source: TLS & "Common Ground" Team, 2017-2018)

01 Channel Chamfers: This process expands the territory of sloughs and channels through the addition of an elevated levee wall that "chamfers" the channel to create new basins and channel geometry. It is conceptually based on patent US969334 which creates a secondary river channel for expeditious flow of flood water. We have modified the principles of the patent to facilitate sedimentation.
02 Mechanical Reclamation: Mechanical Reclamation processes involve the movement and placement of sediment using machines. Specialized marine and terrestrial vessels extract and distribute sediment slurries to facilitate land reclamation and marsh restoration. Varied techniques exist and might be tested at the San Pablo Baylands
03 Plashed Hedgerows: Plashing is a 19 th century technique for making woven fences from living plant material. Typically plashing integrates tensile materials, such as metal wire, into the assembly given the hedges increased strength and allowing for beautiful woven patterns. Plashing is a useful tool for establishment of the Hyper accretion gardens as the bioengineered material that structures the garden may be reinforced.
04 Structural Sediment Accumulators: The geometry of sediment accumulators aims to slow water and control currents in an attempt to promote the accretion of sediments. The structures are open, or permeable, and aim to alter flows and cause turbulence. They area is especially well suited to the hyper accretion sites in conjunction with channel chamfer structures.

²⁸³ David Reymond, "Patents Information for Humanities Research: Could There Be Something?," *Iberoamerican Journal of Science Measurement and Communication* 1, no. 1 (2021): 006–006; Hindle, "Patent Scenarios for the Mississippi River"; Mario Biagioli, Peter Jaszi, and Martha Woodmansee, *Making and Unmaking Intellectual Property: Creative Production in Legal and Cultural Perspective* (University of Chicago Press, 2015).

²⁸⁴ Rain Chen, "Design Patent Map Visualization Display," *Expert Systems with Applications* 36, no. 10 (2009): 12362–74.

05 Sediment Diversions: In channel sediment diversions capture bed load, or bottom sediment, and transport it to a sediment sink in the form of an enclosure or area of sediment deficit. In the San Pablo Grand Baylands, sediment from sloughs and rivers can be captured and reused in other locations with passive, or limited mechanical means, by harnessing peak flow from fluvial systems and cyclical tidal action.
06 Water Gates: The control, or syncopation, or moving water is essential as a new geomorphology is created at the San Pablo Grand Baylands. Automatic tide gates and water gates can control this flow to create ideal conditions for accumulation of sediment, limit the movement of saltwater, and divert fresh water into appropriate areas for irrigation and recharge of groundwater.
07 One Percent Terraforming: Vast areas of the Baylands are flat, and if opened to tidal exchange would become submerged mudflats and open water. Regrading the site using slopes of approximately one percent, would allow for the creation of high and low ground, increase the area of intertidal zone, and create habitat. The benefit of using gradual slopes is that no stabilization is required, and vegetation would establish. Implementing the strategy requires precise terraforming and could be designed to optimize cut and fill so that no imported material is required.
08 Bioengineering Sediment Capture: Bioengineering used living plant material to stabilize earth. When applied to the process of reclamation and reversal of subsidence, bioengineering dovetails effectively with the reuse of sediment slurries from hydrologic dredging. Bioengineered enclosures can retain sediment in a preformed geometry, allowing water to pass through fascines, woven wall, and living enclosures, while retaining and stabilizing the sediment.
09 Biomass Farming: Biomass farming is well suited to the Baylands site and may be integrated with reuse of sediment or treatment of biosolids. An important component of biomass farming is the Baylands integration of the biomass into restoration and reclamation efforts. This may be accomplished through the reuse of willows in site engineering, or the creation of composts to build soil health across the site.
010 Carbon Sequestration (soils): Wetlands and marshes are carbon sinks. The massive subsidence on the site creates the opportunity to bank carbon on the site in the form of organic soils. Monetizing the process of banking carbon could fund reclamation efforts to reverse subsidence. Coupling of this process with biomass farming across the site is a viable option.
011 Forestation: Arboricultural practices and forestation of parcels of the baylands and its margins can shift landscape management practices to longer time horizons and create visual heterogeneity in the site. Trees can also be used to prepare sites for eventually flooding, create snags for wildlife habitat, and potentially become a forestry products industry.
012 Passive Irrigation and Waterworks: Irrigation may become an essential part of re-vegetation efforts and a component of groundwater recharge. Developing passive methods for the movement of water can help structure the site topographically and create visual interest. A series of wells, dry wells, irrigation canals, and subsurface systems could serve as vital infrastructure.
013 Micro-topographies: Subtle terracing, planted depressions in the soil, and furrows on sloped sites can be used to capture surface water on sloped areas of the margin and site. Micro-topographic manipulations can help water infiltration and capture on site. This is particularly well suited to areas with a slope along the margins or in areas where new landforms have been created.
014 Reclamation Enclosures: Predefined reclamation enclosures are used to dewater and contain sediments accumulated through sediment diversions or through mechanical dredge processes. Enclosures, or settling ponds are raised over time, by the addition of sediment rich slurries.
015 Sediment Train: Fixed track systems have been proposed for the construction of levees and can be adapted to the process of restoration. This would allow for the efficient distribution of dredge material, and a reduced carbon footprint when compared to trucking of material. This form of mechanical reclamation utilizes existing railroad tracks to distribute earth.
016 Wetland Terraces: The occurrence of wetland vegetation is determined by the relative depth of water and frequency of inundation, in addition to soil type and other environmental factors. The creation of wetland terraces in sloped and subsided areas would allow for the establishment of wetland ecology independent of sea level and flood datum. Terraces (like rice paddies) necessitate the creation of stepped landforms and allow for relatively shallow water depths on sloped sites.

017 Artificial Seaweeds: <i>The Structure of the benthic zone plays an important role in ecology and sediment dynamics. Artificial seaweeds have been used in coastal areas to ameliorate erosion and may be well suited to open water areas of the site, to create habitat and stabilized sediments. These structures are particularly well adapted for use along the Napa river where tidal flux moves sediment in large areas of open water.</i>
018 Benthic habitat / Artificial Reefs: <i>Artificial reefs are an effective way to create habitat for marine and riverine species. Appropriately designed structures can create spawning areas for fish, and anchorage for marine/riverine invertebrates.</i>
019 Imported Organics (Hay Structures, etc.): <i>The site is in a material deficit due to a century, or more, of soil loss. Importing organic material to build soils and create high ground may partially reverse this process in certain areas. Large hay bales, for example, may serve as a building block for organic soil formation similar to the peaty organics soils that existed on the site prior to levees and farming.</i>
020 Floating Breakwaters: <i>Wave energy in areas of open water, or adjacent to the Napa River, cause erosion and suspend sediments. Floating breakwaters reduce this energy and may be integrated with floating walkways/wetland to provide access and multifunctional infrastructure.</i>
021 Floating Wetlands: <i>Floating wetlands allow for the establishment of wetland vegetation in open water where the bathymetry cannot support plant growth. They can be useful in the creation of habitat for birds, etc., where refuge from open water is important. Although not ideal for large-scale projects, they can be useful at San Pablo Baylands in areas of open water that are not well suited for restoration.</i>
022 Artificial Islands: <i>The construction of artificial islands can be easily accomplished in areas of open water through the construction of simple walls to enclose earth, or through bioengineering techniques.</i>
023 Permeable Dikes / Breakwaters: <i>Removing levees along the Napa river will open the area to tidal exchange. Replacing levees with permeable dikes and breakwaters would allow for the stabilization of soft sediments in adjacent subsided marsh areas and “breathability” between the cyclical flows of water in the river channel and the areas of open water.</i>
024 Channel Sediment Collectors: <i>Sloughs and channels accumulate sediment. Extracting this material not only keeps channels open but allows it to be placed elsewhere in support of reclamation efforts. In areas where sediment currently collects, pumps and siphons can move this material to areas where it is useful.</i>
025 Groundwater Recharge: <i>Rehydration of subsided soils and recharge of groundwater are essential to the long-term success of the baylands. Fresh groundwater is important to stop saltwater intrusion, and as a source of water for living plants. Managing the vertical exchange of water through passive, and mechanical, means are a vital component of restoration.</i>
026 Mollusk Habitat: <i>Mollusks thrive in bay and estuarine environments and can provide important structures for ecological engineering. Shellfish such as Oysters and mussels can be readily cultivated on artificial structures integrated with coastal restoration and may be well suited to the baylands in combination with artificial islands, benthic habitats, and structures for land reclamation.</i>

6. The YO2 Patent Scheme as Anticipatory Framework for Coastal Planning and Design Praxis

The YO2A patent classification scheme was launched by the European Patent Office in April 2018 to organize climate adaptation technologies, including those related to coastal systems, flood control, adaptation of existing infrastructure, human health, and technologies for mapping and sensing the environment. The YO2A scheme is highly relevant to Coastal adaptation and resilience activities as it tags and organizes innovation in a range of coastal and riverine technologies and provides cross-sectoral insight into technological trends - functioning as an anticipatory framework for governance in these emergent sectors. As a mechanism for the management of sequential innovation the YO2A scheme also builds adaptive capacity within the coastal adaptation and resilience space through the diffusion of technological information, increased searchability, and focused patent classifications specifically addressing climate adaptation in coastal, riverine, and urban systems. These core functions address a broad range of coastal issues and can be inform planning and design praxis about technological trends as the dossier continues to grow – contributing to disciplinary capacities for scenario building and strategic planning for probable, plausible, pluralistic, and performative futures. As is observed in the previous five chapters, the struggle to define new coastal futures through technological innovation is a perennial and powerful societal effort that will continue in the context of climate change and perceived environmental risk. Patents provide unique insights about future scenarios and can therefore build adaptive capacity in the face of uncertainty.

Integration of the YO2A with spatial planning and design praxis does raise distinct questions about the role of technology to the allied professions of environmental design and planning, challenging conventions of professional practice limits of disciplinary scope. However, the YO2A's organizational structure and origins in the policy initiatives of the Paris Agreement and Kyoto Protocol can help governments, and planners, make informed decisions about the future of the environment by linking theory to actionable technologies and helping to anticipate technological trends as the cross sectoral technologies of coastal adaptation and resilience are foregrounded by the YO2A. For example, YO2A 30/60 covers "Planning or Developing Urban Green Infrastructure" which now contains almost 22,000 patents from around the world, with

19,583 from China alone. Refined searches reveal some potentially valuable new ideas and business ventures including a system developed by an Australian company DirtSat Inc, for smart city integrated urban roof agriculture³⁸⁵ (figure 59), and a SunPave Inc modular solar paving system described in the patent GB2588296B "Paver with solar panel".³⁸⁶

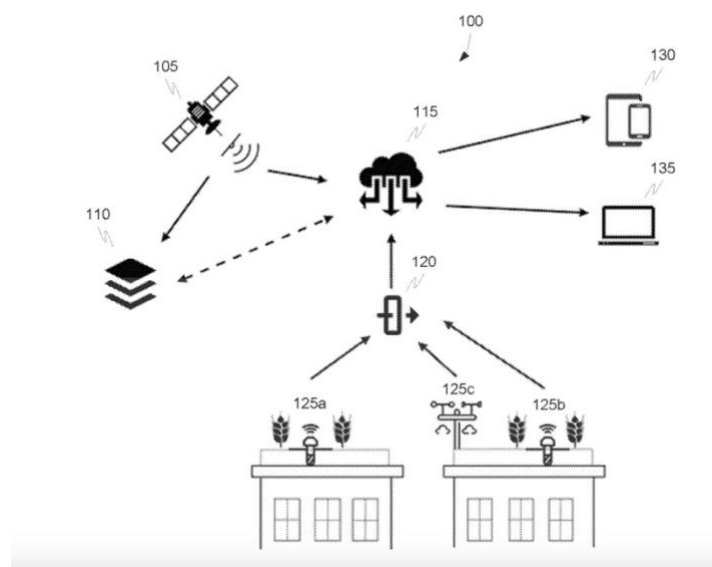


Figure 59: AU2021344973A "Systems and methods of urban rooftop agriculture with smart city data integration" (2023) – a pending patent submitted by DirtSat Inc, included in the new classification for green infrastructure. (Source: European Patent Office, <https://www.epo.org/en>)

Other subsections of the classification scheme show similar potential, including Y02A10/30 covering "Flood prevention and storm water management, Y02A90/10 covering "Information and communication technologies supporting adaptation to climate change" which organizes the weather forecasting or climate simulation systems essential to the analysis of a changing climate. Together the Y02A categories create an institutional mechanism for the diffusion of innovation in coastal

adaptation and resilience technologies and may help greenlight actionable technology by bridging any perceived, or real, lags between new policies and future work in the coastal adaptation and resilience space. As is observed elsewhere in the "green" economy, the patent system can play an important role in expediting innovation through fast-tracked reviewed and coordinated efforts across office dealing with critical and emergent sectors such as green technology.³⁸⁷ Viewing the Y02A patent scheme through the lens of coastal adaptation and

³⁸⁵ Christine Tiballi, Systems and methods of urban rooftop agriculture with smart city data integration, AU2021344973A1, filed September 16, 2021, and issued March 30, 2023.

³⁸⁶ "SUNPave – Tomorrow's Energy Today," accessed June 21, 2023, <https://sun-pave.com/>; "DirtSat | Green Roof Marketplace for Urban Sustainability," accessed June 21, 2023, <https://www.dirtsat.com/>.

³⁸⁷ Lane, "Building the Global Green Patent Highway: A Proposal for International Harmonization of Green Technology Fast Track Programs."

resilience planning reveals its capacities as an anticipatory framework for management of innovation in emergent environmental sectors.

Origins of Y02 and Y02A Patent Classification Scheme

The Y02A was born out of the need to understand technological trends in emergent climate technologies. In 2009/2010 the European Patent Office created a novel computer algorithm to automatically identify, track, and organize all low-carbon technologies in a searchable database accessible to patent examiners as reference for emergent technologies.³⁸⁸ The algorithm created real-time technical dossiers and provided insights regarding emergent, and existing, low-carbon and climate change mitigation tech technologies (CCMTs). In this manner the algorithm helped build responsive and predictive capacities within the patent office targeted on a specific sector of environmental technologies while tracking trends and helping the office keep pace with a rapidly developing technology. The Y02 scheme evolved from this nascent internal research tool, helping to build reference dossier for patent examiners, and establishing an anticipatory framework for technological evolution in climate adaptation sectors – thus linking technological innovation to global policy initiatives.

Essential functions and scope of the Y02 were made public in June 2010 at the UNFCCC's 32 Subsidiary Bodies Session in Bonn, Germany, and since this time the initiative has received ongoing support from the UNFCC as a mechanisms through which to link innovation in climate mitigation technologies to global policy and funding initiatives.³⁸⁹ Ratification of the Paris agreement in 2015 foregrounded the need for technological solutions to climate change, leading to the further development of the Y02 classification scheme and implementation globally. These explicit provisions are evident in the official European Patent Office description, which states; “This class (Y02) covers selected technologies, which control, reduce or prevent anthropogenic emissions of greenhouse gases [GHG], in the framework of the Kyoto Protocol and the Paris

³⁸⁸ Raphael Calel, “Adopt or Innovate: Understanding Technological Responses to Cap-and-Trade,” *American Economic Journal: Economic Policy* 12, no. 3 (2020): 170–201; Raphael Calel, “Adopt or Innovate: Understanding Technological Responses to Cap-and-Trade Online Appendix,” 2019.

³⁸⁹ Victor Veefkind et al., “A New EPO Classification Scheme for Climate Change Mitigation Technologies,” *World Patent Information* 34, no. 2 (2012): 106–11.

Agreement, and also technologies which allow adapting to the adverse effects of climate change.” Today the Y02 patent scheme has expanded to including a range of technologies that extend beyond the original low-carbon focus, tagging patents related to climate adaptation, flooding, infrastructure, health, mapping, etc. under a range of subclasses that address the breadth of climate adaptation and mitigation technologies.

Organizationally this new patent data is organized using the special “Y” designation assigned to monitor new technological developments and to tag cross-sectional technologies that do not fit in a single other section of the International Patent Classification (IPC) and Cooperative Patent Classification (CPC) or have been classified elsewhere. In essence, the Y02 scheme organizes existing, and future, technologies in broadly related and emerging sectors of climate adaptation to provide insights about existing technological capacities and anticipatory framework to track future trends. Having emerged from an algorithm to track, organize, and inform the patent office staff about novel areas of technology in which little is known, the Y02 classification scheme establishes the leading edge of technological trends building adaptive capacity in emergent problem spaces - including the cross-sectoral technologies of coastal adaptation and resilience.

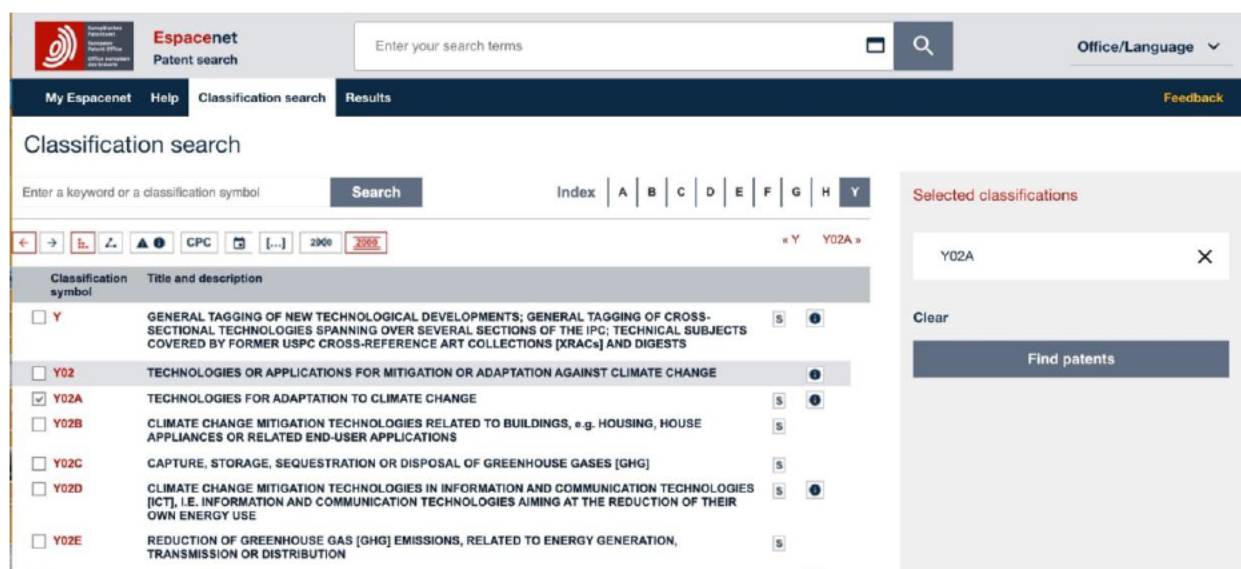


Figure 60: Search Page for the Y02 patent classification scheme on the European Patent Office Website. Easily accessible and free to the public. (source <https://worldwide.espacenet.com>)

The Y02 classification scheme is also public facing (figure 60). The rapid diffusion of technology is also central to the Y02 initiative as well as the policy frameworks of the Paris

Agreement and Kyoto Protocol. As a mechanism for diffusion of technical information the Y02 initiative aims to catalyze innovation through the functions of search and discovery that a publicly accessible database of climate adaptation and mitigation technologies can provide. A recent publication describes is the Y02 initiative as a “dedicated classification scheme for climate change mitigation technologies (CCMTs), where relevant patent publications are “tagged” and classified into a separated scheme which is fully integrated within the Cooperative Patent Classification (CPC). This allows for non-patent experts to search for climate change-related technologies in a more user-friendly fashion.”³⁹⁰ Provisions for user friendly searches mean that technological information can be searched and collated easily, facilitating the diffusion of innovation, and helping inventors, governments, and end users to find relevant technologies and their owners, providing technical, legal, and business information to support strategic decision-making in the field of climate change. This is most clearly accomplished through efficient and freely accessible searches through the EPO <https://worldwide.espacenet.com/patent/cpc-browser#!/CPC=Y02> where users can develop detailed searches, apply filters, and build technical dossiers with limited prior knowledge.

Sectors covered Y02 are far reaching. The Y02 designation now includes eight distinct subclasses Y02A, Y02B, Y02C, Y02D, Y02E, Y02P, Y02P, Y02W, (See table 1 for details) broadly covering the technologies or climate adaption including building systems, carbon technologies, information and communication systems, energy, manufacturing, transportation, waste management, and interconnected sectors of environmental systems including water, green infrastructure, etc. Organizing these technological classes under a single classification heading links socio-technical aspects of patent innovation to the global policy initiatives of the Kyoto Protocol and the Paris Agreement, expanding the technical capacities and knowledge of these initiatives (table 10).

³⁹⁰ Stefano Angelucci, F Javier Hurtado-Albir, and Alessia Volpe, “Supporting Global Initiatives on Climate Change: The EPO’s ‘Y02-Y04S’ Tagging Scheme,” *World Patent Information* 54 (2018): 02.

<i>Y - GENERAL TAGGING OF NEW TECHNOLOGICAL DEVELOPMENTS; GENERAL TAGGING OF CROSS-SECTIONAL TECHNOLOGIES SPANNING OVER SEVERAL SECTIONS OF THE IPC; TECHNICAL SUBJECTS COVERED BY FORMER USPC CROSS-REFERENCE ART COLLECTIONS [XRACS] AND DIGESTS</i>
<i>Y02 - TECHNOLOGIES OR APPLICATIONS FOR MITIGATION OR ADAPTATION AGAINST CLIMATE CHANGE</i>
<i>Y02A - TECHNOLOGIES FOR ADAPTATION TO CLIMATE CHANGE</i>
<i>Y02B - CLIMATE CHANGE MITIGATION TECHNOLOGIES RELATED TO BUILDINGS, e.g. HOUSING, HOUSE APPLIANCES OR RELATED END-USER APPLICATIONS</i>
<i>Y02C - CAPTURE, STORAGE, SEQUESTRATION OR DISPOSAL OF GREENHOUSE GASES [GHG]</i>
<i>Y02D - CLIMATE CHANGE MITIGATION TECHNOLOGIES IN INFORMATION AND COMMUNICATION TECHNOLOGIES [ICT], I.E. INFORMATION AND COMMUNICATION TECHNOLOGIES AIMING AT THE REDUCTION OF THEIR OWN ENERGY USE</i>
<i>Y02E - REDUCTION OF GREENHOUSE GAS [GHG] EMISSIONS, RELATED TO ENERGY GENERATION, TRANSMISSION OR DISTRIBUTION</i>
<i>Y02P - CLIMATE CHANGE MITIGATION TECHNOLOGIES IN THE PRODUCTION OR PROCESSING OF GOODS</i>
<i>Y02T - CLIMATE CHANGE MITIGATION TECHNOLOGIES RELATED TO TRANSPORTATION</i>
<i>Y02W - CLIMATE CHANGE MITIGATION TECHNOLOGIES RELATED TO WASTEWATER TREATMENT OR WASTE MANAGEMENT</i>

Table 10: Y-Y02 Classification Scheme Subject Titles

Y02A and Climate Adaptation

The Y02A scheme was launched by the European Patent Office in April 2018, and was rolled out internationally over the next few years as patent offices around the world integrated specifics of the classification scheme into their systems. The Y02A is unique among the eight subclasses of the Y02 for its focus on environmental and urban systems, infrastructure, and human health, riverine and coastal systems, making it highly relevant to a wide range of adaptation efforts in coastal zones and the broader built environment. The categories cover technologies for coastal and riverine systems, water management, infrastructure adaptation, agriculture, human health, and technologies for mapping, forecasting, and sensing (table 11). The breadth of the initiative is astounding with 702,210 patents covered by the classification, and 394,99 new patents tagged under then since January 1st, 2018.³⁹¹ This current snapshot provides a glimpse of innovation across the 6 sub sections covered by the Y02A. To date the top 8 contributors of Y02A patents include China 568,601, United States 124,377, Japan 114,923, Korea 60,269, International WO 50,940, European Patent 48,948, 34,270, Canada 28,915. It is

³⁹¹ "Espacenet – Search Results," accessed May 17, 2023, <https://worldwide.espacenet.com/patent/search?q=cpc%20%3D%20Y02A%22%20AND%20pd%20%3E%20%2201%2F01%2F2018%22>.

important to note the nearly fourfold quantity of Chinese patents that potentially skew the data through a glut of lower quality patents.

Tracking innovation within the Y02A classification can help national governments and planners make informed decisions about the future of the environment and technology, helping to collate data, analyze trends, and forecast technological capacity. For example, in the United Kingdom the recently published national “Ten Point Plan for a green revolution” sets out the approach government will take to “build back better” by supporting green jobs, and accelerating the path to net zero through renewable energy, sustainable buildings, and the protection of nature. The plan’s commitments to protection of nature includes specific language and financial earmarks for flood protection, stating “We will invest £5.2 billion in a six-year programme for flood and coastal defences including new innovative approaches to work with the power of nature to not only reduce flood risk, but deliver benefits for the environment, nature and communities.”³⁹² Pursuant to the plan, the UK Intellectual Property Office published a report on patent activity in the flood and coastal defense sectors using the Y02A classification to analyze trends in flood adaptive technologies. The report notes an uptick in patent activity in this area with a majority patented technologies being developed in China and less activity domestically within the UK.³⁹³

The Y02A classification is also helping organizations such as the World Bank develop macroeconomic reports and technological forecasts related specifically related to climate adaptation effort. The Global Facility for Disaster Reduction and Recovery (GFDRR) recently (2020) published a global survey of technological innovation and diffusion for climate adaptation, providing the first global analysis of technological trends within sectors of technology covered by the Y02A. Authors of the report found “that a high number of patents in this random sample (89 percent) were indisputably related to adaptation to climate change as described by the UNFCCC, providing reassurance as to the quality of the Y02A tagging scheme.”³⁹⁴ The report offered insight about global invention and diffusion of climate adaptation technologies, including

³⁹² “The Ten Point Plan for a Green Industrial Revolution” (HM Government), https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/936567/10_POINT_PLAN_BOOKLET.pdf.

³⁹³ “Flood and Coastal Defences,” n.d., 24.

³⁹⁴ Antoine Dechezlepretre et al., “Invention and Global Diffusion of Technologies for Climate Change Adaptation,” 2020.

observations that technologies for adaptation were concentrated within a limited number of countries such as China, Germany, Japan, the Republic of Korea, and the United States, low levels of international technology transfer, a mismatch between a countries adaptation needs and their technological capacity, and hinderances in the market resulting from a misalignment between local adaptation needs and market demands. The report also offers guidance on how these issues may be remedied through more tightly coordinated global efforts and additional research addressing adaptation technologies in specific regions.

<i>Y02A TECHNOLOGIES FOR ADAPTATION TO CLIMATE CHANGE</i>
<i>10/00 AT COASTAL ZONES; AT RIVER BASINS</i>
<i>20/00 WATER CONSERVATION; EFFICIENT WATER SUPPLY; EFFICIENT WATER USE</i>
<i>30/00 ADAPTING OR PROTECTING INFRASTRUCTURE OR THEIR OPERATION</i>
<i>40/00 ADAPTATION TECHNOLOGIES IN AGRICULTURE, FORESTRY, LIVESTOCK OR AGROALIMENTARY PRODUCTION</i>
<i>50/00 IN HUMAN HEALTH PROTECTION, E.G. AGAINST EXTREME WEATHER</i>
<i>90/00 TECHNOLOGIES HAVING AN INDIRECT CONTRIBUTION TO ADAPTATION TO CLIMATE CHANGE</i>

Table 11: Y02A Category Headings

Anticipatory Governance and Climate Change Technologies

Collectively the organizational structure of the special “Y” designations of the Y02 predictive algorithms used to track innovation, global patent office infrastructure, and publicly accessible data, including rapid searching, represent a form or anticipatory governance for climate adaptation. Within climate change planning and scientific literature anticipatory governance has emerged as a concept to comprehend and approach climate change through “anticipation and futures analysis, creation of flexible adaptation strategies, and monitoring and action.”³⁹⁵ Anticipatory governance refers to the process of governing in the present to adapt to or shape uncertain futures. A widely cited definition of anticipatory governance defines it as “a broad-based capacity extended through society that can act on a variety of inputs to manage emerging knowledge-based technologies while such management is still possible. It motivates activities designed to build capacities in foresight, engagement, and integration – as well as through their production ensemble.”³⁹⁶ Given the focus on future trends, anticipatory

³⁹⁵ Ray Quay, “Anticipatory Governance: A Tool for Climate Change Adaptation,” *Journal of the American Planning Association* 76, no. 4 (2010): 496–511.

³⁹⁶ Guston, “Understanding ‘Anticipatory Governance.’”

governance is theorized to build capacities in foresight, engagement, and integration within institutions, government, and society, making it particularly useful when conceptualizing approaches to problems such as climate change, national defense, and technological innovation, therefore helping government agencies and other institutions establish future trajectories for investment and innovation.³⁹⁷

Anticipatory governance is now a central feature of climate action. A pivotal moment in climate change debates was the ratification of the Paris Agreement, a legally binding international treaty on climate change. It was adopted by 196 Parties at the Conference of the Parties (COP 21) in Paris, on 12 December 2015, with a stated goal “to limit global warming to well below 2, preferably to 1.5 degrees Celsius, compared to pre-industrial levels.” By establishing future benchmarks, the agreement instigated the need for a global “politics of anticipation” in which contested choices for climate futures could be “woven into the technical elaboration of alternative pathways”.³⁹⁸ The politics of climate anticipation has evolved since ratification of Paris Agreement as global, national, and local; entities attempt to develop strategies to address climate change.

The concept of anticipatory governance challenges notions of planning as a fixed linear process, and instead integrates complexity and change into possible future scenarios – a framework that is proving valuable in sectors planning for climate change. A recent survey article states the following:

“It is becoming evident that the traditional planning paradigm that I [the author] term “predict and plan” will not be adequate to address the highly complex and uncertain issue of climate change. Uncertainty, and the extended planning horizon that climate change calls for, will likely still exist at the time governance decisions are required. In response to this problem, a new approach is emerging in literature and practice. Anticipatory governance, a new model of decision making under high uncertainty based on concepts of foresight and flexibility, uses a wide range of possible futures to anticipate adaptation strategies, and then monitors change and uses these strategies to guide decision making” ³⁹⁹

³⁹⁷ Ramos, “Anticipatory Governance: Traditions and Trajectories for Strategic Design.”

³⁹⁸ Silke Beck and Martin Mahony, “The IPCC and the Politics of Anticipation,” *Nature Climate Change* 7, no. 5 (2017): 311–13.

³⁹⁹ Quay, “Anticipatory Governance: A Tool for Climate Change Adaptation.”

Since no singular strategy can address all possible climate adaptation scenarios the concept of anticipatory governance offers a forward-looking approach to develop plans that address a wide range of futures. With regards to governance structures, it seeks institutional, policy, and planning strategies that build adaptive and anticipatory capacity in society, helping to guide decision making and integrate systems. Anticipatory frameworks have proved valuable in planning possible environmental futures for climate change adaptation and engaging the legal and social aspects of climate resilience planning including possible urban, technological, and environmental futures.⁴⁰⁰ In this context, anticipatory governance becomes integral to social-ecological resilience and that effective management of this process can lead to increased ecological knowledge by building adaptive capacity in the face of climate change and providing future foresight about appropriate responses to environmental risk, etc.⁴⁰¹ This includes technological scenarios and strategies for climate adaptation.

The concept of anticipatory governance is widely applicable to problems with complex and varied possible futures including climate change, national defense, and technological innovation. New and emergent technologies are often created through complex interactions and co-practices between inventors, intuitions, and broader societal assemblages making anticipation of the future a vital component of innovation networks.⁴⁰² Since the future of technology is unknown it is important to create space for new discoveries and track innovation within diverse environmental sectors. These are core and well-established functions of the global patent system and a specific objective of the Y02 scheme. Take for example the recent advances in artificial intelligence that promise to revolutionize climate mitigation and adaptation efforts by making climate models and integrated responses more effective. Innovation in this emergent sector is most effectively tracked through analysis of patent data now organized by the Y02 scheme, revealing evidence of knowledge spillover between advances in AI and adaptation technology.

In the context of climate adaptation and mitigation, technological innovation and patent trends offer distinct insights about future environmental scenarios while simultaneously

⁴⁰⁰ Edward W De Barbieri, "Urban Anticipatory Governance," *Fla. St. UL Rev.* 46 (2018): 75.

⁴⁰¹ Boyd et al., "Anticipatory Governance for Social-Ecological Resilience."

⁴⁰² Alvial-Palavicino, "The Future as Practice. A Framework to Understand Anticipation in Science and Technology."

revealing the role of the patent system of adaptive governance and new knowledge infrastructures. For example, in sectors such as climate engineering the 1.5-degree threshold for global temperature increase is central to the discussion of polycentric and anticipatory frameworks for coordinated actions to mitigate climate change.⁴⁰³ Theoreticians in this space have been grappling with how to govern and track this emergent and contested sector of technology. A recent article summarizes the issue “We characterize governance of solar geoengineering as an anticipatory challenge here because the very contours of the ‘object of governance’ remain uncertain and largely even unknowable.”⁴⁰⁴ Importantly, knowledge and anticipation of these trajectories has planetary implications as geoengineering technologies propose to alter the earth’s climate through technical intervention and insights about this process can be gained through patent analysis.⁴⁰⁵ As these performative futures take shape, technology, and the Y02A, have the potential to contribute to future discourse, envisioning, and practices.

Although no universal framework exists for anticipatory governance in practice, a recent survey article Karlijin et al. summarizes the possible approaches that have emerging from research and literature on the subject. The authors neatly organize this into four approaches that capture the range of anticipatory governance and the mechanisms through which they may be applied, which they summarize as follows: 1) Probable futures, strategic planning, and risk reduction, 2) Plausible futures, enhanced preparedness, and navigating uncertainty. 3) Pluralistic futures, societal mobilization and co-creating alternatives. 4) Performative futures, critical interrogation, and political implications.⁴⁰⁶ The range of approaches outlined by the authors provide insight into the practices of anticipatory governance and help comprehend how the approaches to a spectrum of “futures” can become essential component of environmental design and planning praxis.

⁴⁰³ Simon Nicholson, Sikina Jinnah, and Alexander Gillespie, “Solar Radiation Management: A Proposal for Immediate Polycentric Governance,” *Climate Policy* 18, no. 3 (2018): 322–34.

⁴⁰⁴ Aarti Gupta et al., “Anticipatory Governance of Solar Geoengineering: Conflicting Visions of the Future and Their Links to Governance Proposals,” *Current Opinion in Environmental Sustainability* 45 (2020): 10–19.

⁴⁰⁵ Paul Oldham et al., “Mapping the Landscape of Climate Engineering,” *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 372, no. 2031 (2014): 20140065.

⁴⁰⁶ Karlijin Muiderman et al., “Four Approaches to Anticipatory Climate Governance: Different Conceptions of the Future and Implications for the Present,” *Wiley Interdisciplinary Reviews: Climate Change* 11, no. 6 (2020): e673.

Y02A as an Anticipatory Framework for the probable, plausible, pluralistic, and performative futures

The allied fields of environmental design and planning are integral to climate adaptation, and coastal resilience efforts. The well-defined disciplinary scopes, and working methods, of landscape architecture, architecture, urban and regional planning, and civil and environmental engineering inextricably link them to real world sites and environmental systems through praxis – making them a vital link between global strategies for adaptation and the contingencies of coastal sites. However, pressing questions remain regarding the relationship of these allied disciplines to technology, innovation, and patented technologies. Inclusion of specific sub-classes in the Y02A classification scheme for technologies related to the built environment and coastal adaptation present an opportunity to link professional practice to broader technological trends.

The relative newness of the Y02A (implemented 2018-2020) classification scheme, and general obscurity of the patent system within the discourses of coastal adaptation and resilience, create a unique situation. On one hand, the existence of a global framework for the management and diffusion of innovation in coastal sectors is a provocation, or call-to-action, with the possibility to facilitate positive change in communities and ecosystems. On the other, the mechanisms and processes through which novel adaptation and resilience technologies are invented, tested, and implemented through environmental/spatial design, planning, and engineering praxis are nascent. Given this recent emergence of the Y02A it is reasonable to look towards the Y02 (super-classification of Y02A originating c. 2015) scheme for indications of trajectory within the field. Research shows the Y02 has the potential to function as part of a complex assemblage of how cities, regions, and countries develop approaches to climate adaptation. For example, southwest European cities are using data from the Y02 scheme to help guide research and development activities in the region.⁴⁰⁷ Recent studies at the intersection of climate change and patent data suggest that policymakers can use the Y02 results to get greater clarity on how to allocate resources for R&D and support climate change technologies.⁴⁰⁸ In this

⁴⁰⁷ Şiir Kılıç, "Sustainable Development of Energy, Water and Environment Systems Index for Southeast European Cities," *Journal of Cleaner Production* 130 (2016): 222–34.

⁴⁰⁸ Su Jung Jee and Sugandha Srivastav, "Knowledge for a Warmer World: A Patent Analysis of Climate Change Adaptation Technologies" (arXiv.org, 2021).

manner Y02, and its sub-classifications including Y02A, helps provide foresight and is integral to measuring and analyzing environmental innovation and creates a feedback loop between environment and technology. Supporting global, and local, initiatives on climate adaptation and mitigation through technology forecasting.⁴⁰⁹

In essence anticipatory framework create space for emergent and unforeseen changes and aims to build foresight and predictive capacity within a broad range of systems, including technological, urban, and environmental systems impacted by climate change. Anticipatory approaches therefore help conceptualize scenarios for the future and imagine the tools required to achieve goals, creating processes for governing in the present while adapting to uncertainty. As Karlijn Muiderman et al. argue this relates to a spectrum of activates, such as scenario building, that help frame probable futures, plausible futures, pluralistic futures, and performative futures.⁴¹⁰ Diving deeper into this range of approaches reveals how technological innovations covered by the Y02A can contribute to, and help conceptualize, these coastal futures through the practices of design and planning.

Probable Futures consider as a starting point that “futures are scientifically uncertain and complex, but still assessable in terms of probable and improbable future risks.”⁴¹¹ In the assessment of probable futures, the anticipation is to assess these risks, to inform strategic policy trajectories on how to minimize future risks. This often involves cost/pricing scenarios, forward-looking information services, economic modeling, technological forecasting, analysis of climate statistics, environmental impact assessments, etc. Essentially the types of everyday planning and forecasting that governments and other agencies are regularly involved in as they consider approaches to coastal adaptation and resilience.

Practical projects, such as budgeting for a seawall replacement, storm clean-up, and issues related to predictable flooding are all part of a probable future and can be understood through the lens of technology. Take for example the processes of seawall upgrades in Sydney

⁴⁰⁹ Germà Bel and Stephan Joseph, “Climate Change Mitigation and the Role of Technological Change: Impact on Selected Headline Targets of Europe’s 2020 Climate and Energy Package,” *Renewable and Sustainable Energy Reviews* 82 (2018): 3798–3807.

⁴¹⁰ Muiderman et al., “Four Approaches to Anticipatory Climate Governance: Different Conceptions of the Future and Implications for the Present.”

⁴¹¹ Muiderman et al.

harbor which aim to increase biodiversity. New material and design standards can be informed by technological innovation, helping to align advanced technologies with the pragmatics of local planning. Novel concrete mixtures like ecological concrete, By Econcrete Tech Ltd.

(US9538732B2 & AU2014217435B2 Methods and matrices for promoting fauna and flora growth) are engineered to meet international construction standards and can be effectively integrated into marine construction projects (figure 61). Importantly, by tracking innovation in ecological concrete, or a range of other applicable technologies planners and designers can develop an understanding of leading-edge systems that can serve as an anticipatory framework for probable futures.

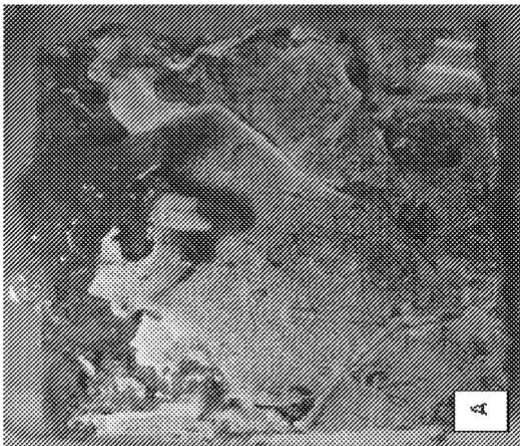


Figure 61: Patent image of biological growth on concretes using mixtures from US9538732B2 & AU2014217435B2 "Methods and matrices for promoting fauna and flora growth." (Source: European Patent Office, <https://www.epo.org/en>)

The detailed categories of the Y02A (tables 12-17) facilitate the exchange of technical information across a range of interrelated systems relevant to the planning of probable futures. This includes Y02A10/00 covering 'at coastal zones; at river basins,' and a range of subclasses that directly link patent innovation to Y02A 20/404, Y02a 20/144 Wave Energy, Y02a 30/254 Roof Garden Systems, and Y02A 30/60 Planning or developing urban green infrastructure. Within these categories a dossier of established, and novel, technologies are available for integration into the pragmatics of planning and design. As technologies evolve, planners, governments, and communities may track innovation and build networks through metadata associated with patent submissions, linking innovators to potential partners. For example, Fresh Creek Technologies Inc and its partner StormTrap, manufacture a range of modular stormwater management systems that city managers can integrate into projects.⁴¹² Knowledge of StormTrap technologies, such as US9695584B2 'Inclined plates for Combined

⁴¹² "Stormwater Liter, Trash & Debris Removal | CSO Trash Control," Stormtrap, accessed June 21, 2023, <https://stormtrap.com/products/trashtrap/>.

Sewer Outflow' (CSO), can obviously be communicated through advertising, conferences, and word of mouth, but the metadata about inventors, and assignee, associated with the patent can also provide links to inventors and corporate entities actively engaged in developing new forms of urban infrastructure (figure 62).⁴¹³

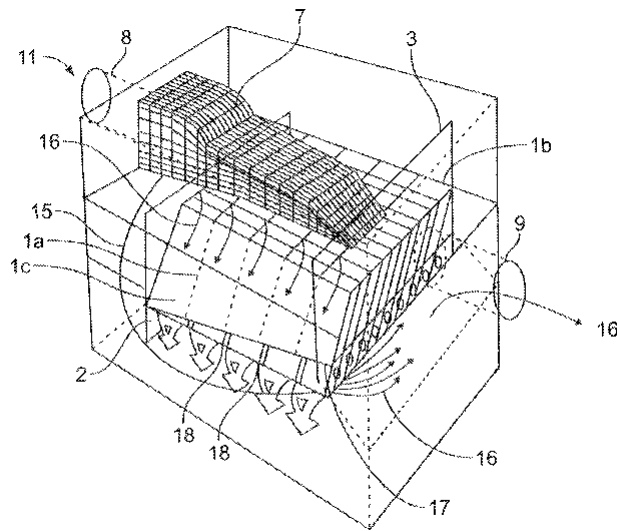


Figure 62: US9695584B2 Inclined plates for Combined Sewer Outflow (CSO) (2017) – metadata from the patent and technical details can inform planners of advances in the field. (Source: European Patent Office, <https://www.epo.org/en>)

Plausible Futures consider that “the future contains irreducible uncertainties and that multiple plausible future trajectories are feasible.”⁴¹⁴ In this approach, anticipation becomes a mechanism for deliberation, thus building adaptive capacities and preparedness that allows for uncertain futures as their trajectories unfold. This involves a range of options built on shared knowledge between experts and other constituencies. This may be accomplished by processes of mapping, participatory modeling, and

other actions that involve the exchange of information based on local and subject area expertise. Technology transfer is among the methods that are prioritized here including local knowledge holders and facilitate bottom-up community involvement in decision-making and those that are expert-driven. Technology transfer is a central function of the Y02A, helping to build technical capacities through the exchange of expertise.

Mechanisms for enabling the transfer of knowledge and development of plausible coastal futures range in scope and complexity from the SAMOA pathways of the United Nations that aims to build technical capacity in Small Island Developing States, to localized participatory mapping exercises, or even recurring conferences that bring together scientists, community, and

⁴¹³ Dennis R. Moran, Walter C. Trnka, and Hans De Bruijn, Inclined plates for CSO, US9695584B2, filed October 24, 2013, and issued July 4, 2017.

⁴¹⁴ Muiderman et al., “Four Approaches to Anticipatory Climate Governance: Different Conceptions of the Future and Implications for the Present.”

industry, to approach large scale coastal planning initiatives. Similarly, the 100 Resilient Cities initiative, supported in part by the Rockefeller Foundation and partners, aims to build urban resilience through social and technical pathways. The network of 100 cities spans continents, aiming to link urban resilience networks and catalyze innovation. The projects statement on technology looks at urban centers for the development of resilience technology and also the end user, focusing primarily on digital technology for smart cities, analytics, and mapping. Sectors covered by Y02A 90/10 Information and communication technologies [ICT] supporting adaptation to climate change through weather forecasting or climate simulation.

Withing the discrete domains of coastal planning anticipatory frameworks for plausible futures are common and widespread, making them vital to the implementation of innovative planning strategies and technologies. We can look towards sustained long term planning conferences, such as the State of the Coast conference in Louisiana, that aims to create an “interdisciplinary forum to exchange timely and relevant information on the dynamic conditions of Louisiana’s coastal communities, environment, and economy and to apply that information to existing and future coastal restoration and protection efforts, policies, and decision-making.” In addition to the plenary session and keynote lecture, a robust list of donors and exhibitors

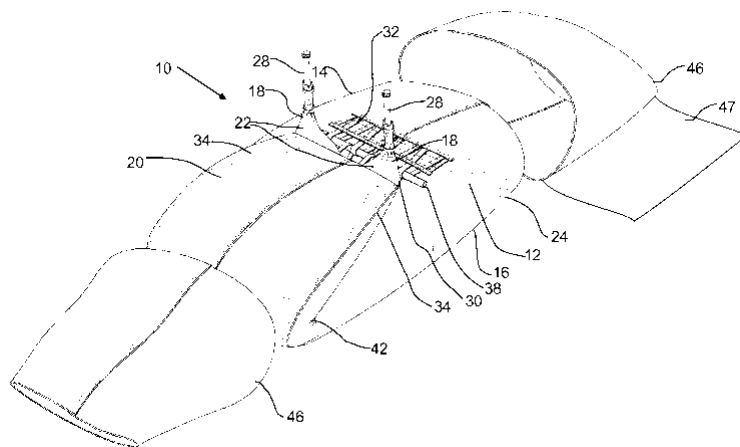


Figure 63: US9297133B2 “Fluid fillable structure” (2016). Flexible flood infrastructure exhibited a State of the Coast. (Source: European Patent Office, <https://www.epo.org/en>)

showcase new technologies that address the audiences and practical elements of initiating Louisiana’s coastal masterplan. Technologies exhibited at the conference help communicate a range of technological options that address the plausible futures discussed at the conference.

Exhibitors such as Tetrattech, Louisiana State University, ORA, all have intellectual property covered by the Y02 and achieve knowledge

transfer through this process. Consider briefly the water filled flood control structures US9297133B2 “Fluid fillable structure “manufactured by Aqua Dams Gulf Coast (figure 63).⁴¹⁵ Their rapidly deployed coffer dams, exhibited at the State of the Coast in 2014, inform end users in subsided and flood prone lands how to protect their property using the system.⁴¹⁶ This type of entrepreneurial approaches to addressing plausible coastal futures integrate technology into practice through community engagement and knowledge exchange as part of regionally specific conferences.

Pluralistic futures consider “embedding multiple future worlds, shaped by interaction, and dependent on diverse interpretations of the world.”⁴¹⁷ This pluralism is achieved by mobilizing diverse societal actors that may collectively develop actionable pathways for change. This type of co-creating enables the conceptualization of new and transformed futures through the process of creating experiential futures in simulations, envisioning, or other immersive experience. In practice this may include processes such as design workshops that integrate futures into present day environments or design competitions that help mobilize collective action towards a desired state. Envisioning through visual representation and narrative is now common practice in coastal adaptation and resilience planning, particularly through the professional practices of architecture, landscape architecture, and urban planning who embrace future projections as agents of change. This is readily observable in the range of design and planning competitions addressing the issue including the widely cited Resilience By Design program and others such as the Changing Course competition that developed pluralistic futures for the Mississippi River Delta.⁴¹⁸ As is discussed in chapter 1 & 5, design and planning competitions not only lead to the creation of novel technology such as oyster-tecture but may also be informed by patent innovation studies through the creation of technical dossiers and analysis of patented technology.

⁴¹⁵ “Gulf Coast AquaDams in Abbeville, LA,” Web Leads, accessed June 21, 2023, <https://GULFCOASTAQUADAMS.COM/>.

⁴¹⁶ James Andrew Mills and Gregory Allan Parrent, Fluid fillable structure, US9297133B2, filed September 5, 2014, and issued March 29, 2016.

⁴¹⁷ Muiderman et al., “Four Approaches to Anticipatory Climate Governance: Different Conceptions of the Future and Implications for the Present.”

⁴¹⁸ “Changing Course,” accessed April 9, 2022, <http://changingcourse.us/>; “Changing Course,” Restore the Mississippi River Delta, accessed June 19, 2023, <https://mississippiriverdelta.org/changing-course/>.

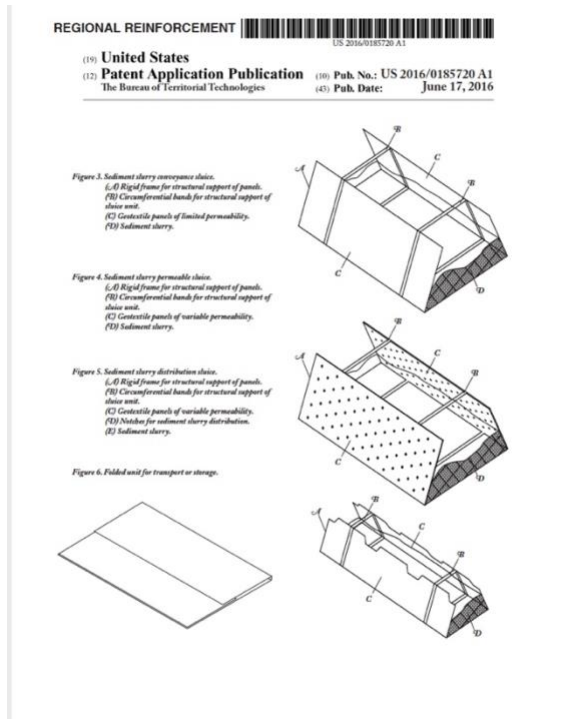


Figure 64: A speculative technology for "Regional Reinforcement" developed by the design team during Dredgefest California

Pluralistic futures are also central to design and planning pedagogy which sometimes addresses issues of coastal adaptation and resilience. These projects can be designed with innovation and patent research as a central theme. For example, In the summer of 2016, the author (Richard Hindle) and Neeraj Bhatia (CCA) led a workshop as part of DredgeFest California, focused on sedimentation and earthworks in the California Delta. During the weeklong workshop, participants and workshop leaders were asked by the DredgeFest organizers to develop responses to a series of scenarios that covered the pluralistic futures in the delta. After a short initial exercise exploring existing technologies from the patent archive and extrapolating their territorial impact, four new technologies were created by the team who operated under the pseudonym "Bureau of Territorial Technologies."⁴¹⁹ Each invention addressed issues ranging from subsidence and accretion of sediment to aquifer recharge and levee reinforcement (figure 64). By developing a specific technology and understanding how it would alter the broader the landscape, it allowed designers to quickly understand the implications of their design proposals, moving back and forth between technological invention, and pluralistic regional transformation,

⁴¹⁹ Richard L Hindle and Bhatia Neeraj, "Territorial Technologies," 2016.

ultimately facilitated design experimentation at the scale of the territory and at the detailed scale of a specific technology developed by the designer.

Performative futures engage the future through “fabrications, or sociotechnical imaginaries that are speculative, but still performative in calling into being certain privileged visions of the future.” Their capacity for speculation allows for alternate readings and potential to emerge and for their political implications and material consequences to be investigated. Methods such as narrative, image making, serve as heuristics that allow for diverse futures to

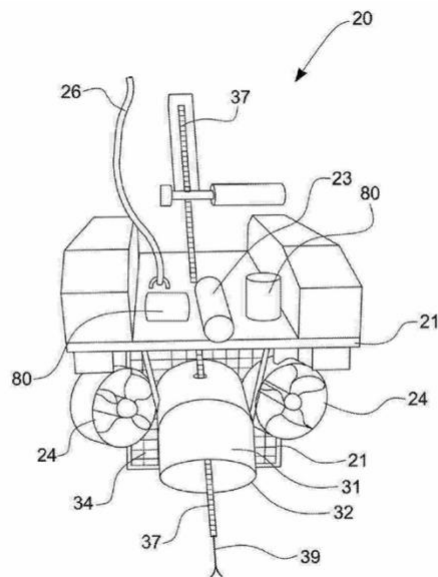


Figure 65: GB2567452A "Method apparatus and system for controlling fish" – one of the numerous autonomous vehicles designed to hunt invasive species. (Source: European Patent Office, <https://www.epo.org/en>)

explored and analyzed for their political and social implications by opening discourse and framing new potential. Performative futures are often central to the realization to environmental scenarios and new ecologies and can be tracked through technological innovations in the Y02A. Take for examples the debate around invasive species in which new environmental scenarios for managing wildness and autonomy are conceived.⁴²⁰ Theorists in this space look towards technologies

such as the RangerBot, designed by scientists in Queensland Australia to attack invasive starfish, as examples of integrated robotics and computation employed in the management of invasive species – evoking a novel form of Anthropocene wilderness. A specific patent subclass Y02A 90/40 covers the “Monitoring or fighting invasive species” which includes a range of related technologies such as rovers to collect invasive lionfish or devices for the filtering of algae blooms (figure 65).⁴²¹

Given the projective nature of technology, and the anticipatory capacities of the patent

⁴²⁰ Cantrell, Martin, and Ellis, “Designing Autonomy: Opportunities for New Wildness in the Anthropocene.”

⁴²¹ Alan Martin Darius et al., Method apparatus and system for controlling fish, GB2567452A, filed October 12, 2017, and issued April 17, 2019.

system, performative futures weave a distinct thread through the Y02, and Y02A classification. Patent trends offer insights about future environmental scenarios while simultaneously revealing the role of the patent system of adaptive governance and new knowledge infrastructures. Knowledge and anticipation of these trajectories has planetary implications as is evident in evolving discourse and debate on geoengineering. In the emerging geoengineering sector few laws or government entities are in place to manage developments given the extraterritorial nature of the proposals and global impact making foresight of future trends important. According to a recent paper on the subject, “In the absence of a governance framework for climate engineering technologies such as solar radiation management (SRM), the practices of

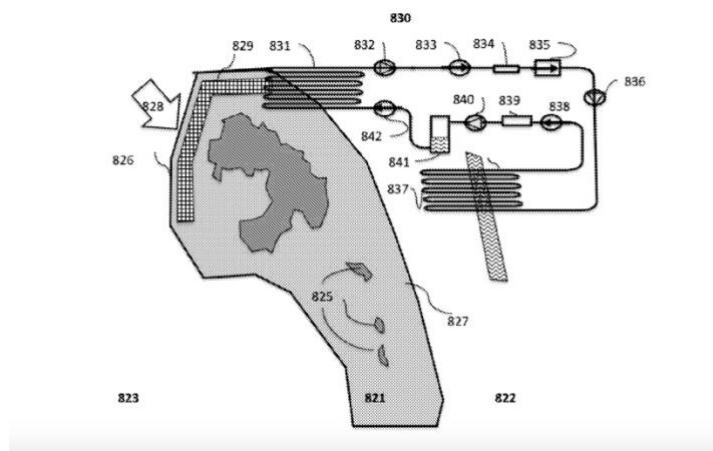


Figure 66: WO2022091107A1 “system and method for reducing temperature of water in coral reef and adjacent ocean” – an example of speculative environmental engineering patents that aim to save coral reefs. (Source: European Patent Office, <https://www.epo.org/en>)

scientific research and intellectual property acquisition can de facto shape the development of the field.”⁴²² In this speculative technological space new frameworks patent law are also being proposed including patent pools that ensure the free use and diffusion of technologies to “save the planet.”⁴²³

Irrespective of the validity of existing geoengineering technology, it is interesting to take note, just in case

these projections of future climate solutions take shape. We can see this debate taking shape in the context of coastal adaptation and resilience through the emergence of coral reef restoration technologies. A recent survey article reveals a disconnect between coral reef restoration patents and trends in scientific literature, pointing towards the need to peer-reviewed science to be translated into actionable technologies.⁴²⁴ Of course these issues should be addressed, but a review of recent reef patents raises questions of a geopolitical nature. For example,

⁴²² Oldham et al., “Mapping the Landscape of Climate Engineering.”

⁴²³ Anthony E Chavez, “Exclusive Rights to Saving the Planet: The Parenting of Geoengineering Inventions,” *Nw. J. Tech. & Intell. Prop.* 13 (2015): 1.

⁴²⁴ Cassandra Roch, Sebastian Schmidt-Roach, and Carlos M Duarte, “Coral Restoration Patents Are Disconnected from Academic Research and Restoration Practitioners,” 2023.

WO2022091107A1 “system and method for reducing temperature of water in coral reef and adjacent ocean” and the now abandoned patent AU2016101704A4 “A method for saving coral reefs from bleaching by cloud intensification” initially submitted by the Sydney Institute of Marine Science, both require the existence of global technologies, and political actors, capable of altering marine environments and atmospheric systems (figure 66).⁴²⁵

Discussion

The YO2A scheme is highly relevant to Coastal adaptation and resilience activities as it tags and organizes innovation in a range of coastal and riverine technologies and provides cross-sectoral insight into technological trends. As a mechanism for the management of technological innovation the YO2A scheme builds anticipatory capacity within the coastal adaptation and resilience space through the diffusion of technological information, increased searchability, focused patent classes specifically addressing climate adaptation in coastal, riverine, and urban systems. Tagging patents related to climate adaptation essentially collates large datasets of past, present, and future patented technologies related to the subject area and helps structure searches, citations, and build knowledge infrastructure. Tracking innovation in climate adaptation technologies also allows for the diffusion (i.e., sharing) of innovation to be streamlined and identification of technological trends to emerge in distinct categories. In this manner the YO2 scheme serves as an anticipatory governance framework for managing technological innovation in the context design and planning praxis, providing technical insights for probable, plausible, pluralistic, and performative futures.

Coastal Adaptation and resilience planning cuts a distinct transect through technologies covered by the YO2A classification scheme. Within design, planning, and scientific communities it is widely accepted that coastal adaptation and resilience requires a wholesale reconfiguration of how we live with water and organize the social, ecological, and technical systems that converge in coastal zones. A recent publication on coastal “structures” states this succinctly; “Coastal resilience necessitates not only new infrastructural strategies but a fundamental

⁴²⁵ Sunit Tyagi, System and Method for Reducing Temperature of Water in Coral Reef and Adjacent Ocean, WO2022091107A1, filed December 24, 2020, and issued May 5, 2022.

transformation in understanding how cities might relate to the water around them.”⁴²⁶ This paradigm shift suggest a more expansive list of technologies extending though cities, regions, and natural systems to reformulate the water, sediment, nutrient flows, and natural process that interact within coastal anthromes in which human and natural systems are coupled, including agriculture, human settlement (i.e. buildings and infrastructure), engineered coastlines, river systems, etc.⁴²⁷ From this perspective, the Y02A provides insights regarding a range of interconnected coastal technologies in addition to those structures directly related to the coastline – building anticipatory governance through the adaptive capacities of technological innovation.

Table 12 Y02A/10 Technologies for Adaptation to Climate Change at coastal zones and river basins

Y02A 10/00 AT COASTAL ZONES; AT RIVER BASINS
Y02A 10/11 HARD STRUCTURES, E.G. DAMS, DYKES OR BREAKWATERS
Y02A 10/23 DUNE RESTORATION OR CREATION; CLIFF STABILISATION
Y02A 10/26 ARTIFICIAL REEFS OR SEAWEED; RESTORATION OR PROTECTION OF CORAL REEFS
Y02A 10/30 FLOOD PREVENTION; FLOOD OR STORM WATER MANAGEMENT, E.G. USING FLOOD BARRIERS
Y02A 10/40 CONTROLLING OR MONITORING, E.G. OF FLOOD OR HURRICANE; FORECASTING, E.G. RISK ASSESSMENT OR MAPPING

Table 13 Y02A 20/00 Water conservation; Efficient water supply; Efficient water use

Y02A 20/00 WATER CONSERVATION; EFFICIENT WATER SUPPLY; EFFICIENT WATER USE
Y02A 20/108 RAINWATER HARVESTING
Y02A 20/124 WATER DESALINATION
Y02A 20/131 REVERSE-OSMOSIS
Y02A 20/138 USING RENEWABLE ENERGY
Y02A 20/141 WIND POWER
Y02A 20/142 SOLAR THERMAL; PHOTOVOLTAICS
Y02A 20/144 WAVE ENERGY
Y02A 20/146 USING GREY WATER
Y02A 20/148 USING HOUSEHOLD WATER FROM WASH BASINS OR SHOWERS
Y02A 20/15 LEAKAGE REDUCTION OR DETECTION IN WATER STORAGE OR DISTRIBUTION
Y02A 20/152 WATER FILTRATION
Y02A 20/20 CONTROLLING WATER POLLUTION; WASTEWATER TREATMENT
Y02A 20/204 KEEPING CLEAR THE SURFACE OF OPEN WATER FROM OIL SPILLS
Y02A 20/208 OFF-GRID POWERED WATER TREATMENT
Y02A 20/211 SOLAR-POWERED WATER PURIFICATION
Y02A 20/212 SOLAR-POWERED WASTEWATER SEWAGE TREATMENT, E.G. SPRAY EVAPORATION
Y02A 20/30 RELATING TO INDUSTRIAL WATER SUPPLY, E.G. USED FOR COOLING
Y02A 20/40 PROTECTING WATER RESOURCES
Y02A 20/402 RIVER RESTORATION
Y02A 20/404 SALTWATER INTRUSION BARRIERS

⁴²⁶ Catherine Seavitt Nordenson Nordenson, Guy, Chapman, Julia, *Structures of Coastal Resilience.*, 2018.

⁴²⁷ Kurth et al., “Defining Resilience for the US Building Industry”; Lazarus, “Toward a Global Classification of Coastal Anthromes.”

Y02A 20/406 AQUIFER RECHARGE
Y02A 20/411 WATER SAVING TECHNIQUES AT USER LEVEL

Table 14 Y02A 30/00 Adapting or protecting infrastructure or their operation.

Y02A 30/00 Adapting or protecting infrastructure or their operation
Y02A 30/14 Extreme weather resilient electric power supply systems, e.g., strengthening power lines or underground power cables
Y02A 30/24 Structural elements or technologies for improving thermal insulation
Y02A 30/242 Slab shaped vacuum insulation
Y02A 30/244 using natural or recycled building materials, e.g. straw, wool, clay or used tires
Y02A 30/249 Glazing, e.g. vacuum glazing
Y02A 30/254 Roof Garden systems; Roof coverings with high solar reflectance
Y02A 30/27 Relating to heating, ventilation or air conditioning [HVAC] technologies
Y02A 30/272 Solar heating or cooling
Y02A 30/274 using waste energy, e.g. from internal combustion engine
Y02A 30/30 in transportation, e.g. on roads, waterways or railways
Y02A 30/60 Planning or developing urban green infrastructure

Table 15 Y02A 40/00 Adaptation technologies in agriculture, forestry, livestock or agroalimentary production

Y02A 40/00 Adaptation technologies in agriculture, forestry, livestock or agroalimentary production
Y02A 40/10 in agriculture
Y02A 40/13 Abiotic stress
Y02A 40/132 Plants tolerant to drought
Y02A 40/135 Plants tolerant to salinity
Y02A 40/138 Plants tolerant to heat
Y02A 40/146 Genetically Modified [GMO] plants, e.g. transgenic plants
Y02A 40/20 Fertilizers of biological origin, e.g. guano or fertilizers made from animal corpses
Y02A 40/22 Improving land use; Improving water use or availability; Controlling erosion
Y02A 40/25 Greenhouse technology, e.g. cooling systems therefor
Y02A 40/28 specially adapted for farming
Y02A 40/51 specially adapted for storing agricultural or horticultural products
Y02A 40/58 using renewable energies
Y02A 40/60 Ecological corridors or buffer zones
Y02A 40/70 in livestock or poultry
Y02A 40/76 using renewable energy
Y02A 40/80 in fisheries management
Y02A 40/81 Aquaculture, e.g. of fish
Y02A 40/818 Alternative feeds for fish, e.g. in aquacultures
Y02A 40/90 in food processing or handling, e.g. food conservation
Y02A 40/924 using renewable energies
Y02A 40/926 Cooking stoves or furnaces using solar heat
Y02A 40/928 Cooking stoves using biomass
Y02A 40/963 Off-grid food refrigeration
Y02A 40/966 Powered by renewable energy sources

Table 16 Y02A 50/00 in human health protection, e.g. against extreme weather

Y02A 50/00 in human health protection, e.g. against extreme weather
Y02A 50/20 Air quality improvement or preservation, e.g. vehicle emission control or emission reduction by using

<i>catalytic converters</i>
<i>Y02A 50/2351 Atmospheric particulate matter [PM], e.g. carbon smoke microparticles, smog, aerosol particles, dust</i>
<i>Y02A 50/30 Against vector-borne diseases, e.g. mosquito-borne, fly-borne, tick-borne or waterborne diseases whose impact is exacerbated by climate change</i>

Table 17 Y02A 90/00 Technologies having an indirect contribution to adaptation to climate change.

<i>Y02A 90/00 Technologies having an indirect contribution to adaptation to climate change</i>
<i>Y02A 90/10 Information and communication technologies [ICT] supporting adaptation to climate change, e.g. for weather forecasting or climate simulation</i>
<i>Y02A 90/30 Assessment of water resources</i>
<i>Y02A 90/40 Monitoring or fighting invasive species</i>

Conclusion

As anthropogenic and urbanized coastal systems become more technologically advanced, networked, logistical, ecologically novel, and integrated, a strategy is required for the allied disciplines of environmental design and planning to engage the socio-technical processes that operating within these complex systems. This dissertation illustrates how the patent system, and innovative technologies disclosed within it, have impacted the biology, morphology, and development patterns of coastal systems for centuries and how this trend is projected to continue in the context of a changing climate. However paradoxical, innovation is a vital societal response to environmental risk and is imperative for coastal adaptation and resilience planning efforts occurring in cities and regions around the world. Leveraging the distinct agency of patented technology, and the patent system, offers one strategy for the advent and advancement of novel environmental technologies – operationalizing broad sociotechnical processes to help build more sustainable, adaptive, and equitable coastal Anthromes.

Establishment of Y02A patent classification scheme (circa 2018-20) for “Technologies for Adaptation to Climate Change” resolves one small, yet important, piece of the wicked problem of coastal resilience and adaptation, providing knowledge infrastructure for the adaptive capacities of technology to contribute to global efforts. The relative newness of the Y02A and the perceived distances between patents, innovation, and the allied professions of environmental design and planning, presents a distinct opportunity to shape coastal futures. Many questions remain regarding the invention, prototyping, testing, and implement the environmental technologies of the future – yet this work is imperative, and the allied profession of environmental design and planning are poised to be instrumental in the invention application of this new technological substrate through professional practices, research and development, and strategic partnerships. Facilitating the translation of coastal innovation into praxis, this research documents the scales, scope, complexity of implementing innovative technologies in large-scale coastal works and points towards the potential hybrid vigor between the domains of technological innovation and professional practices of urbanization, planning, design, and coastal management. The Y02A has created an entirely new system to track innovations in green

infrastructure, artificial coral reefs, river restoration, etc., and now requires ground-level strategies to operationalize the most promising advances into coastal, urban, and landscape systems. Within this new paradigm are opportunities to expand disciplinary scope, build better coastal infrastructure, and link advanced technology to coastal development practices.

Observations and Reflections on Research Case Studies

The case studies presented as part of this dissertation document the scales, actors, and agency, of the patent system and patented technologies, operating within coastal system and their impact of the morphology, biology, and development of coastal Anthromes. Optimists may see the potential for novel technology to help build more sustainable and equitable coastal futures in the face of climate change and sea level rise. Pessimists may see industrial progress and economic imperatives reshaping environmental systems and extracting profit. Both possibilities exist simultaneously and are true, yet the intellectual, cultural, and policy, climate emerging around issues of climate adaptation and resilience will undoubtedly define which of these plausible futures become a reality. Take for example the case of artificial reef technology discussed in chapter 3 which embodies the dialectic. In Japan artificial reef technologies emerged through collaborative ventures between governments and private industry, leading to the birth of an ecological technology industry to support fisheries. Comparatively, In the United States the artificial reef sector was born out of a joint waste-management program with the automobile industry and Environmental Protection Agency (EPA) to build reefs from scrap tires, contributing to skepticism about the claims and objectives of artificial reef programs in the United States. Today, in the context of coastal adaption and the Y02A we observe a shift in artificial reef technology, from systems designed to augment fishing grounds, towards systems that aim to project coastal ecosystems and restore coral reefs through advanced research and technological innovation. Within this relatively well-known example the *problematique* and imperatives of coastal innovation are clear, chronicling how the cultural awareness of ocean health and sustainability leads to shifts in the technical substrate that defines coastal anthromes.

Among the cautionary tales of corporate interest, or the failed attempts to find alternative coastal stabilization technologies, readers of this dissertation may also see the

upsides of a productive collaboration between technological innovation and coastal adaptation and resilience efforts. The research documents the advent of novel technologies through planning practices, diverse actors and inventors engaged in the process of systemic change, the parallel evolution of theoretical horizons and related technology, actionable pathways for new coastal infrastructure paradigms, and the productive collaborations between patent knowledge infrastructure and the anticipation of future scenarios across scales, geographies, and cultures. Today, with the existence of the Y02A classification scheme, a distinct opportunity exists to integrate these processes to the built environment and coastal systems through the design and planning praxis – helping to implement and invent the next layer of coastal infrastructure. Planners, designers, and governments will all play a role in the application, and invention, of critical climate adaptation technology making initiatives such as the Y02A central to evolution of these technical fields.

As is documented in chapter 1 through the advent of oyster-tecture the processes of coastal adaptation and resilience planning does lead to the creation of new intellectual property and novel technologies. However, these inventive processes do not occur in a vacuum, and analysis of patent innovations in the oyster-tecture and living breakwater sectors reveal that prototyping of related technologies began in the 1980's and advanced through the 1990's with pilot projects and patents by Mark and Sherwood Gagliano and August Muench. Geography separated these processes of invention, having emerged through the unique environments observed in Florida and Louisiana. However the core technologies were further siloed by social networks and professional practices that overlooked prior-art and advanced seemingly novel oyster-tecture systems developed in the as part of the coastal resilience planning processes in response to Super-Storm sandy by SCAPE, SeArc, and Econcrete. The 20–40-year lag, or chasm, is cause for concern and further discussion as it appears technological innovation chronicled by patent innovation outpaced the rate of discovery in design and planning. Precedents for living breakwaters have existed in patent form and proposals to the USACE through the work of Edmund Boots and the Sebecon Reef Association in 1973, yet these groundbreaking works remain entirely unknown, instead of part of the canon for how to build with nature. The Y02A classification presents the opportunity to close this chasm and foreground innovative

technologies by making them easier to find and disseminate by collapsing geographical boundaries and issues of accessibility, making innovation accessible to all – including planning professionals engaged in adaptation and resilience work.

Scale also presents a significant challenge to coastal adaptation and resilience works, with no single government organization or private entity equipped to comprehensively address the challenges of a changing coastline. The detailed cases presented in chapter 2 explore how issues of scale and entrenched practices of large engineering monopolies, such as the United States Army Corps of Engineers (USACE), are confronted by new actor-networks attempting to develop new standards and practices in coastal systems through the advent of technology. An actor-network perspective on coastal adaptation and resilience efforts also directly addresses issues of geographical scale by recasting the problem space as a question of network size, thus linking efforts and integrating broad constituencies typically consider outsiders in the realm of coastal engineering. In this reformulation patents serve as important intermediaries, representing and taking the place of actors, in these new assemblages as network capacity is being built. In this system the potential contribution of the Y02A is clear, as it serves to organize innovation in coastal sectors and build new networks through the communication of technical information related to issues with enormous geographical scales. By engaging broader constituencies in the process of envisioning new forms of coastal infrastructure, layers of sociotechnical ingenuity can contribute to collective envisioning of coastal futures.

Of course, It is wise and prudent to be weary of corporate interest and involvement in environmental planning. Patents have a long been intertwined with industrial revolutions and capitalism, but also with the birth of entirely new sectors of ecological technology. As discussed in Chapter 3, corporate ecologies are doubled edged with the capacity for manipulation and environmental tragedy or becoming foundational to national identity. Reflecting on the positives outcomes with examples from the Japanese ENSEI, suggests an alternate narrative in which coordinated planning efforts for marine innovation hubs, including social programs, research institutes, private/public partnerships helped found an ecological technology sector - resulting in the invention of hundreds of artificial reef modules, upwelling devices, and a modernized fishing industry. Looking towards the future of ecological engineering in marine

systems, the ENSEI program provides a valuable precedent addressing the scale and complexity through layered planning that builds expertise and technical capacity across government and industry. Patents played an important role establishing the field, offering prospect and opportunity, to Japan's largest manufacturing companies. This know how was eventually transferred to the United States through a series of international conferences and translation of Japanese patents for manufacturing by high level government consultants. In the emergent sectors of coastal adaption and resilience coordinated planning is also required across disciplines, social network, and industry partners, to build everything from artificial reefs to new mapping software.

The adaptive capacities of technology are perennial and ongoing – a process tracked, archived, and managed by the patent system. Since no “textbook” exist for global coastal adaptation and resilience the adaptive, and archival, capacities of the patent system are especially valuable, and they serve as innovation knowledge infrastructure for coastal sites and systems. As is discussed in chapter 4, the technical database of the patent system can provide reference for the iterative steps of discovery as well as a heuristic for solving complex environmental problems such as those related to subsidence and sea-level rise at a detailed site-level. The perceived distances between the patent system and local adaptation and resilience planning creates a significant barrier that may be partially overcome by the Y02A as the distinct categories of technology, and accessibility, couched within the language of climate adaption provide reference for future works. In the case of the 2017 Bay Area Challenge, technical dossiers and detailed analysis of landscape typologies integrated with technology, showcase the potential of leveraging innovation knowledge infrastructure to help solve coastal adaptation challenges. The team's broader vision for the San Pablo Baylands and Grand Bayway was shaped in dialogue with innovative technologies, including proposals to utilize the site as a living lab to further innovation in coastal adaption and resilience. This process linked the probable future of sea-level rise to the plausible future of strategic site redevelopment, helping to project new coastal scenarios through grounded research.

Paradigm shifts are afoot, including in the way in which infrastructure is conceived of and developed. Largeness and permanence have been replaced with ideas of modularity, flexibility,

decentralization, localized, and hybrid forms of infrastructure. These novel design principles are altering critically important infrastructure such as water, telecommunications, and electricity, as well as coastal infrastructure. Chapter 5 explored this phenomenon through the lens of coastal adaption and resilience, foregrounding how new paradigms in infrastructure are paralleled by innovation in patented technologies. As theoretical frontiers are established one may imagine this mutualism to continue with leaders in the field inventing new technologies and technologists advancing theory through praxis. The adaptive capacities of technology are central to this formulation in which theories of coastal resilience keep pace with, or reflect, new developments in technology and planning. Examples of this run throughout the YO2A, especially in newly established areas of innovation, such as green infrastructure where advances in artificial intelligence and living systems promise to transform management of the urban landscape.

As society plans for probable, plausible, pluralistic, and performative coastal futures, frameworks for anticipatory governance will continue to gain relevancy as a mechanism to prepare for the unknown and the likely scenarios arising from a changing planet. Technological change is among the factors resulting from, and informing, this process of anticipating change. The YO2A operates as an anticipatory governance framework for climate adaptation technologies and is uniquely situated to contribute to this evolving dialectic in the complex social-ecological-technical systems converging in coastal zones by linking planning and envisioning processes to technological change. At the most pragmatic level coastal managers and city planners can stay abreast of technology, such as ecological sea walls or concrete mixtures, for integration into near-term projects. On the planetary scale, innovation in climate engineering or ocean-based carbon sequestration can be tracked through patents, helping to define the contours of speculative and performative coastal futures.

Together the case studies, histories, and convergent narratives, intersecting with the patent system and future prospects of the YO2A offer a timely provocation to expand and integrate environmental design and planning praxis with broader sociotechnical processes. The perceived distance between technological innovation and the professional standards of architecture, planning, and allied disciplines has long been a subject of debate. The eminent architect Richard Buckminster Fuller raises the issue poetically in 'An operating manual for

spaceship earth' where he situates the ongoing need for innovation against the ongoing trajectories of further specialization. For Fuller this begins with the great anticipatory voyages of the "sea masters" established the need specialization and disciplinarity, thus he posits Leonardo da Vinci as the lauded archetype of the "comprehensively anticipatory design scientist" who may liberate humanity. Fuller's meta critique of disciplinary scope and boundaries continues through the essay, concluding with a suggestion to architects, planners, and engineers to think outside the conventions of practice, stating "you are accustomed to thinking only in dots and lines and a little bit in areas does not defeat the fact that we live in omnidirectional space-time and that a four dimensional universe provides ample individual freedoms for any contingencies."⁴²⁸ A not so subtle hint that the operating manual for spaceship earth may in fact be found through the utilization of appropriate technology and not conventions of professional practices – a notion he famously explored through his Guinea pig-b experiments and 28 patented inventions.⁴²⁹

Within the confines of architectural discourse, the issue of patented technology has periodically, and contentiously, emerged. In 1890, the British architects Flockton & Gibbs submitted a patent to protect their "invention" of a new spatial organization, improving the plans of government buildings and institutions through novel spatial and structural configurations. The patent was met with intense criticism by architects and patent examiners on both sides of the Atlantic who viewed it antithetical to conventions of professional practice, and, soon after, the discipline rapidly and unanimously dropped the patenting of architectural plans.⁴³⁰ More recently, the polemic between spatial planning, architectural praxis. and patented technology, was explored by the Office of Metropolitan Architecture in a series of "Universal Modernization Patents" in which the office describes social condensers, strategies for the void, timed erasure, loop tricks, variable speed museums, skyscraper loops, and other ideas that defined OMA's original contributions to architecture.⁴³¹ Today the discipline of architecture is addressing issues of ownership and authenticity in the context of the digital age and researchers offers critical reflections on open source and 3-d printing technology that promise to disrupt

⁴²⁸ R.B. Fuller, *Operating Manual for Spaceship Earth*, A Clarion Book (Southern Illinois University Press, 1969),

⁴²⁹ Buckminster R. Fuller, *Inventions: The Patented Works of Buckminster Fuller* (New York: St. Martins Press, 1983).

⁴³⁰ "Patenting Plans," *American Architect and Architecture*. xxx (November 29, 1890): 137–38.

⁴³¹ Rem. Koolhaas, *Content: OMA-AMO*,. London: Taschen, 2004.

traditions.⁴³² These contentious and speculative forays exploring the interrelationship between patents and architecture posit architecture as opposed, or contrary, to the patent system through their engagement with spatial planning, urban dynamics, and open source.

Societal and environmental shifts are underway that may necessitate that the relationship between professional practice and patent technology innovation be reconsidered. The Y02A classification scheme, and its cousin Y02B “Climate Change Mitigation Technologies Related To Buildings,” have the potential to help shape praxis, pedagogy, and link the allied fields of environmental design to a range of initiatives that expand disciplinary scope. For example, In the United States there is a nationwide effort is afoot for Landscape Architecture to be designated a S.T.E.M (science, technology, engineering, and math) discipline. S.T.E.M designated programs are academic programs that fall under at least one of the approved categories from the United States Department of Homeland Security (DHS). To support this effort, the American Society of Landscape Architects (ASLA) has pursued STEM designations through advocacy with DHS. One criterion used by the DHS to evaluate STEM is innovation, research, and the development of patented technology. A recent white paper published by the ASLA and authored by a consultancy, aims to link the profession to innovation in climate adaptation technologies through the classifications established by the Y02A patent classification scheme. The authors of the white paper find that “Within Y02A are more detailed categories of technologies to support climate change adaptation. An ASLA analysis of the technologies in Y02A shows that at least 22 of them relate directly to topics covered in the landscape architecture curricula or have been the subject of research and innovation projects by landscape architecture students and faculty.”⁴³³ Similar changes are afoot in professional practice where the legal statutes that define professional licensure in New York State, Ohio, and Missouri, now include clauses for patent works contributing to maintenance of professional standards.⁴³⁴ Within this we see a concerted effort to expand the technical capacities, and perceptions, of landscape architecture.

⁴³² Antoine Picon and Wendy W Fok, *Digital Property: Open-Source Architecture* (John Wiley & Sons, 2017).

⁴³³ “2022_ASLA_STEM_White_Paper.Pdf,” accessed May 11, 2023, https://www.asla.org/uploadedFiles/2022_ASLA_STEM_White_Paper.pdf.

⁴³⁴ “Missouri,” accessed June 6, 2019, https://www.asla.org/uploadedFiles/CMS/Government_Affairs/State_Government_Affairs_and_Licensure/State_Documents/Missouri2015.pdf.

As professions such as landscape architecture, architecture, and planning approach the complex challenges of coastal adaptation and resilience more robust, open, and comprehensive approaches to innovation are required. These shifts in technological capacity are occurring at exactly the time when they are needed the most. Coastal regions continue to be impacted by climate change and new policies and plans are implemented, technological innovation will parallel this process. At the global level strategic initiatives are now in place for technology transfer and expansion of technical capacity for Small Island Developing States (SIDS), with opportunities to address critical issues of sea-level rise and adaptation through spatial planning coupled with technological innovation. Countries such as Canada and the United Kingdom have resilience and “green revolution” plans in place that aim to leverage the innovation in fire, flood, and coastal infrastructure through public private partnerships. And at the city level the network of 100 Resilient Cities, and their satellite municipalities, are poised for an influx of resilience technology resulting from innovation in hardware, software, and fixed infrastructure.

Contemporary Snapshot: technological pathways for climate adaptation and resilience

The context for coastal adaptation resilience work is changing in real-time as global initiatives and local action plans take shape with Y02A poised as a productive partner for the coordination of sequential innovation in emergent environmental problem spaces. Coastal systems are “ground zero” for the impacts of climate change, and therefore emblematic of and layers of society, governance, professional practice, and policy are being strategically reorganized to coordinate adaptation within these complex social-ecological-technical systems. The context for adaptation and resilience works are changing and the pathways are being built at national and international levels to facilitate the transition in economy, policy, and society – ushering in an organizational shift from early phase resilience planning to coordinated global efforts.

A snapshot of contemporary initiatives, provided below, situates this dissertation in the context of local, national, and international adaptation and resilience planning – positing that the allied disciplines of environmental design and planning, dialogue with the Y02A, are a pivotal lynchpin grounding technological pathways in coastal sites and systems. This transition is timely

as the pioneering adaptation and resilience works of the past two decades phases out. Initiatives such as the 100 resilient cities, funded for a 5-year period, have built networks around resilience planning but also reached expiry in 2019 – leaving a void in global strategic planning. Design and planning competitions such as the Resilience by Design completion is now more than a decade old, and related resilience programs such as the Bay Area challenge occurred more than five years ago. In this “beta” phase we can observe nascent responses to long-term challenges built through discrete programs, but as the issue of climate adaptation become more acute global initiatives are taking shape to align with local efforts. Y02A is one part of this assemblage, operating at the global sociotechnical level to coordinate innovation and provide knowledge infrastructure to a range of local, national, and global, initiatives that will reshape coastal regions, economies, and society. This includes a range of events and plans that will define the next phases of adaptation and resilience planning, such as:

- The Department of Commerce’s U.S. Patent and Trademark Office (USPTO) and the National Oceanic and Atmospheric Administration (NOAA) announced on February 28th, 2023, a collaborative work program to promote and advance further innovation in climate and “green” technology areas. This was enacted by executive order by Biden administration to build technical capacity in response to climate adaptation. The focus of the program is of the collaboration is a work-sharing initiative that focuses on the intersection of intellectual property (IP) and climate and environmental technologies. The program, featuring the exchange of employees over the course of up to a year, will enhance cooperation among the agencies and strengthen their respective work to incentivize greater innovation in these critical areas.⁴³⁵
- The Canadian Government Publishes the final draft of its first climate adaptation strategy in June 2023, outlining the layers of governance and social action required to meet targets for carbon mitigation and responses to climate events such as wildfires, food, heatwaves, and thawing permafrost. Central to the plan are the adaptation of infrastructure, innovation through public private partnerships, and revision to professional standards across disciplines. As a pretext the Canadian Intellectual property office (CIPO) published a report on climate mitigation technologies to assess domestic technological capacities.⁴³⁶

⁴³⁵ “NOAA, U.S. Patent and Trademark Office Create Work-Sharing Program to Advance Green Technology.”

⁴³⁶ “Patenting-Climate-Change-Mitigation-Technologies-En.Pdf,” accessed June 27, 2023, <https://ised-isde.canada.ca/site/canadian-intellectual-property-office/sites/default/files/attachments/2022/patenting-climate-change-mitigation-technologies-en.pdf>.

- The heads of the five largest intellectual property (IP) offices, including the European Patent Office (EPO), Japan Patent Office (JPO), Korean Intellectual Property Office (KIPO), China National Intellectual Property Administration (CNIPA), and United States Patent and Trademark Office (USPTO), collectively known as the IP5 Offices, met in June 2023 to discuss the role of IP5 in addressing climate change through an accessible and inclusive IP system. The meeting included a tour of the National Oceanic and Atmospheric Administration's (NOAA), a review of the joint working programs between USPTO and NOAA, and focused panels of innovations in climate adaptation and the blue economy.
- In November 2020 the UK government released a 'ten-point' plan for a green industrial revolution. The plan states that innovation has a key role in helping to achieve carbon net zero and makes provision for climate adaptation and resilience technology. As part of the plan, the UK Patent office developed a series of technical reports for sectors of adaptation technology, including the worldwide patent landscape in relation to flood and coastal defense patents to assess capacities and guide investment. The report documents innovation in a variety of flood and coastal defense methods including dams, levees, weirs, sea walls and diversion canals, and points towards the need for regional innovation.⁴³⁷
- The United Nation's strategic plan for a "Decade of Ocean Science for Sustainable Development" known as the "Ocean Decade" was launched in 2021, foregrounding the need for coordinated global planning around issues of ocean health and management. The plan explicitly addresses issues of technology and innovation this as part of their Implementation plan which includes provision for technology transfer and development. This aims to address critical issues such as ocean pollution, as well as build technological capacity for Small Island Developing States (SIDS) and others in critical need. Science, innovation, and policy, are the major drivers of the Ocean Decade.⁴³⁸
- In 2020 the World Bank Publishes "Invention and Global Diffusion of Technologies for Climate Change Adaptation: A Patent Analysis" using data collected from the Y02A classification scheme. The report analyzes technological capacities across a range of sectors related to global adaptation efforts, thus validating the efficacy of the Y02A in tracking innovation in these emergent sectors. In the report the World Bank makes specific recommendations related to building technological capacities in developing nations through more efficient technology transfer and targeted innovations are required to address issues such as flooding and drought.⁴³⁹
- World Intellectual Property Organization (WIPO) organizes regional workshops on innovation and sustainable development for Small Island Developing States (SIDS) to provide updates on "Leveraging IP in the Blue Economy Sectors". The series of virtual

⁴³⁷ "A Worldwide Overview of Flood and Coastal Defence Patents," GOV.UK, accessed July 10, 2023, <https://www.gov.uk/government/publications/a-worldwide-overview-of-flood-and-coastal-defence-patents>.

⁴³⁸ "Ocean Decade – The Science We Need For The Ocean We Want," accessed July 10, 2023, <https://oceandecade.org/>.

⁴³⁹ Dechezlepretre et al., "Invention and Global Diffusion of Technologies for Climate Change Adaptation," 2020.

workshops was organized by the WIPO in cooperation with the University of the West Indies (UWI), the Japan Patent Office (JPO) and the Caribbean Climate-Smart Accelerator, with the support of financing from the Funds-In-Trust Japan Industrial Property Global.⁴⁴⁰

- European Patent Office launches a series of focused reports on the changing environment. The most recent, published online in 2023, highlights Innovation in fire prevention, firefighting, wildfire control and forest restoration. Bringing to attention the innovation landscape associated with specific adaptation sectors chronicles how access to the technical information contained in patents can respond to global climate challenges. Importantly, the series of focused adaptation reports from the EPO will continue across a range of sectors and global issues.⁴⁴¹
- The 100 resilient cities initiative concluded in 2019 after 5 years of funding. The organization published a series of reports the summarize key findings of the program, including a special report on technology. The study finds that cities are integral to technological innovation and that innovation in resilience technology will continue to expand as demand increases, stating “In looking for solutions to resilience challenges, it is clear that the ability of technology to play a meaningful role in both better understanding and mitigating shocks and stresses is increasing every day as new products and services are brought to market and mature”⁴⁴²

As global, national, and regional approaches to climate adaptation and resilience take shape through the policies, initiatives, reports, and strategical plans, outlined above, important questions remain regarding the grounding and testing of novel technologies in real-world sites and systems. Bridging between global technological change and coastal systems, the YO2A and professional practices of environmental design and planning become integral to the translation of technical knowledge and coastal development and management practices. As this dissertation argues, patented technology and the patent system are intertwined with coastal systems and this parallel evolution of systems can be operationalized to advance adaptation and resilience works. The key findings of this research project not only reveal the latent role of patented technology in coastal systems but also the structural changes required to strategically leverage innovation networks through design and planning praxis.

⁴⁴⁰ European Patent Office, “IP5 Offices Discuss Office-Led Initiatives on Climate-Related Innovations,” accessed July 10, 2023, <https://www.epo.org/news-events/news/2023/20230621.html>.

⁴⁴¹ Office, “Firefighting Technologies.”

⁴⁴² “Resilience-Point-of-View-Technology.Pdf,” accessed June 29, 2023, https://resilientcitiesnetwork.org/downloadable_resources/UR/Resilience-Point-of-View-Technology.pdf.

Key Findings & Recommendations from Case Studies

- Patented technologies impact coastal systems and development patterns across a range of scales, from satellite linked tsunami forecasting to ecologically engineered materials that enable establishment of marine organisms on coastal infrastructure.
- Technological innovation provides one of several viable pathways to operationalize coastal adaptation and resilience across a range of scales and geographies. The Y02A has the potential to unlock this pathway as global resilience planning takes shape through establishment of innovation knowledge infrastructure.
- Coastal Anthromes are impacted by a range of human activities, requiring innovation in coastal adaptation and resilience technologies across a range of sectors, from aquaculture to construction of urban storm water systems. Sub-classes of the Y02A organize sequential innovation across these sectors.
- The process of technological innovation in the coastal adaptation and resilience problem space is ongoing, and occurs with, or without, the involvement of planning and design professionals. Increased involvement by the allied professions of environmental design and planning has the potential to shape coastal futures and build new pathways.
- Design and planning competitions generate new technologies through innovative planning programs. This process needs to be better understood and managed to lead to more efficient outcomes and resource allocations.
- Design and planning competitions have the potential implement and foreground new technologies through the integration of patent studies and knowledge infrastructure into project development. Without innovation studies and development of prior-art dossiers, lags, or chasms, in invention and diffusion may occur. The Y02A provides an effective mechanism for the diffusion of innovation and may help prevent lags or chasms in the process of discovery and invention.
- Diverse actors and networks are involved in the process of coastal innovation. Engaging these broad constituencies in the process of coastal innovation helps shape coastal futures and catalyze systemic change within entrenched power structures. Patents serve as intermediaries in this process, helping to build network capacity.
- New categories of technology covered by the Y02A focus on green infrastructure, water, coastal technology, etc., making them highly relevant to the cross sectoral technologies of climate adaptation and resilience, including those that interact with coastal systems. As information regarding these new systems expands, the Y02A provides an anticipatory

governance framework for the planning of coastal futures. This includes the pragmatics of planning for probable environmental risk and scenario building for pluralistic futures.

- New paradigms for coastal infrastructure require new forms of technology. Innovations organized by the newly established subclasses of the Y02A keep pace with evolving paradigms in infrastructure development. Novel forms of coastal infrastructure have the potential to impact a diverse range of coastal communities.

Y02A as Praxis: an innovation model for coastal adaptation and resilience

The preceding case study chapters document the ongoing role of patented technology, and the patent system in coastal systems, arguing that this process and can be operationalized to advance adaptation and resilience efforts through the creation of new technological pathways and establishment of knowledge infrastructure for future problem solving. Observations made

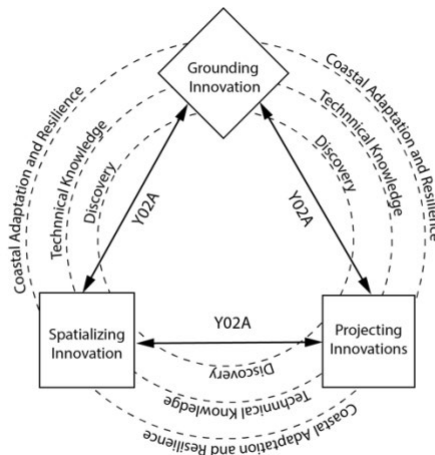


Figure 67: Diagram of a three-part problem space addressing the need to integrate patented technology and patent data into design and planning praxis.

during the case study research make it clear that although persistent, the role of patents and innovation in the coastal adaptation and resilience problem space is often messy, incongruent, and seemingly uncoordinated. In response, an innovation model, posited in here, makes strategic recommendations to build adaptive capacities and resilience in coastal systems through integration of spatial planning and

design praxis with the Y02A patent classification scheme. The relative newness of the Y02A, and perceived distance between sequential innovation within the allied disciplines of environmental design and planning practice, creates a unique situation that the innovation model aims to address through the integration of patent datasets and novel technologies into praxis. Evidence in support of strategic model that integrate the Y02A into praxis is found throughout the case study research. For example, the technical knowledge infrastructure of the patent system, discussed comprehensively in chapter 4, remains siloed from the work of landscape architecture and urban/environmental planning yet has the potential to integrate with other robust spatialized knowledge infrastructure, such as Geographical Information Systems (GIS) - linking patent dataset and technical details to planning workflows to facilitate modeling and knowledge transfer. Of course, establishment of the Y02A patent classification scheme raises other issues related to operationalization and implementation that are highlighted by the case studies. Most

notably is the distance between the intuitional mechanisms of the patent system and the inherently spatial, environmental, social, political, and durational, biological, and planetary systems operating in coastal zones and other anthromes. As is documented by the case studies, bridging between these domains has the potential to create link technological innovation to coastal futures through the praxis of planning and design. Take for example the invention of oyster-tecture, discussed in chapter 1, which chronicles the invention of novel ecologically informed coastal infrastructure developed within the context adaptation and resilience planning efforts and also the existence of prior-art in the field, revealing a chasm in the realization of core technologies. Addressing this, and other concerns highlighted by the case study research, the innovation model makes strategic recommendations for linking the Y02A to professional practice and built works to build network capacity and problem solve critical issues in coastal adaptation and resilience.

Integrating the Y02A classification scheme to the process of coastal adaptation and resilience (i.e. the innovation model) is conceptualized as a three-part problem space involving; 1) Spatializing Innovation: the integration of Y02A patent data and metrics into planning and design praxis so it may inform development and management of coastal systems at geographical scales, 2) Grounding Innovation: building innovative coastal systems through pilot projects, testing, and implementation of novel technologies and new social assemblages, integrated with the Y02A and environmental planning and design praxis, 3) Projecting Innovations: developing core technologies and establishing technological frontiers in adaptation technology categories of the Y02A through partnerships between practitioners, research universities, industry, communities, compressing the distance between local, regional, and international coastal networks through innovation (figure 67).

Spatializing Innovation

The geographical dimensions of coastal adaptation and resilience efforts are enormous, spanning the globe and innumerable cultures, industries, and ecologies. Building adaptive capacity within these interconnected systems requires broad layers of society to engage in the imperative of coastal innovation. Addressing the scale and layered systems that converge in the

coastal zone presents a distinct challenge for planners and governments to coordinate, therefore consolidating, or speeding up, network capacity. This is integral to effectively manage the diffusion of innovation in the sector. The long-term process of innovation in coastal systems can be effectively managed through the hybridization of two robust forms of knowledge infrastructure, the Y02A classification scheme and Geographical Information Systems (GIS). In general terms this involves the creation of technological “layers” within GIS that collate with Y02A, augmentation of Y02A classification to include specific environmental metadata to facilitate the integration with GIS and planning processes, and coordinated modeling and analysis that provides a feedback loop for spatialized innovation (figure 68).

Within the domains of planning and design the knowledge infrastructure of GIS effectively addresses issues of scale, duration, and network length, providing robust spatial data for planning urban, regional, and natural systems. GIS is a robust spatial program, database, user interface utilized by a range of design and planning professions to integrate and coordinate layered information for a range of planning activities. It seamlessly integrates layered spatial information to help comprehend the dynamic processes and systems converging at known locations on the earth’s surface. Cities and regions around the world utilize GIS as a planning and decision-making tool, creating an effective mechanism for integrating technical information into

planning praxis. Technical information in patent documents, patent data, and other metrics can be effectively integrated through the Y02A, linking the most robust database of adaptation technologies in existence to established spatial and environmental planning methods. In the specific case of coastal adaptation and resilience integrated Y02A & GIS has the potential to coordinate a range of environmental technologies

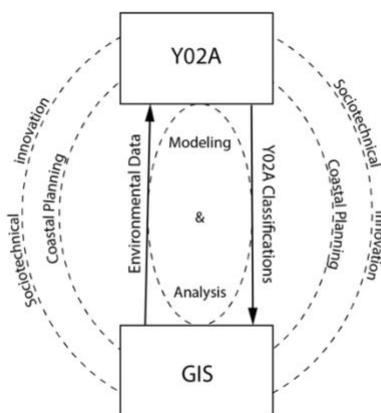


Figure 68: Diagram describing the spatialization of innovation through the integration of GIS and patent knowledge infrastructure. (by Author)

including innovative structures for the stabilization of coastlines and green infrastructure for cities.

Spatializing innovation through Integration of Y02A datasets into GIS databases consolidates information and workflow, linking two powerful forms of knowledge infrastructure. Since environmental technologies differ from hermetic “black box” technologies in that they engage the contingencies of site, natural & cultural systems, biology, duration, and process, additional metadata may be required to build effective systems that integrate technical information with GIS. As is seen through history, the patent system can be operationalized to address technical issues related to environmental management, such as is observed in the creation of the US Department of Agriculture from the early meteorological and germplasm research undertaken by the United States Patent Office in the 19th century. More recently we can look towards Japanese artificial reef innovation under the Ensei program, discussed in chapter 3, and the current Japanese patent classification system that includes biological and geographic metadata to properly classify artificial reef technology. The Japanese F-terms are used by the Japanese Patent Office (JPO) for exactly this purpose and may be adapted to a range of environmental technologies to improve their applicability and link them to GIS databases. The F-terms are JPO's original search keys that cover multiple aspects (e.g., purpose, use, structure, material, manufacturing method, processing, and operational method, and means of control) prepared for a relevant technical area ("theme"). The F-terms build upon the international patent classification (IPC) and the Cooperative Patent Classification (CPC). As mentioned in chapter 3 the F-term for artificial reefs includes theme codes that are further classified based on A) Installation configurations, B) Structures, C) Characteristics other than Structures, D) materials, E) Target Organisms. Each of these criteria is further subdivided accordingly to provide high-fidelity metadata for artificial reef planning. The result is a classification system that indicates position in a marine system, targets species, etc., creating a clearer picture of innovation in the artificial reef sector by linking innovation to biology and marine systems.

When considering the technologies of climate and coastal adaptation the F-terms offer distinct benefits as they can provide important meta data for integration of technical information into GIS layered dataset. Modeling and Analysis of existing, and proposed technologies may

increase adaptive capacities and expand knowledge in the interrelated coastal sectors. This modeling and analysis are recursive, facilitating planning scenarios and discovery.

Grounding Innovation:

Linking the Y02A initiative to real-world projects is essential to operationalizing the adaptive capacities of technology, and grounding policy and funding initiatives for coastal adaptation and resilience, including the rapidly expanding national, regional, and urban level plans currently in development. Of course, coastal innovations may bypass the sequential processes of design and planning, however these professional practices provide a vital layer for coordination, review, and implementation, that are discrete to disciplinary domains. The allied professions of environmental design and planning are therefore integral to the implementation of Y02A innovation and translation of technological advancements into coastal adaptation and resilience plans. As is documented in case study chapter 2 through the search for alternative coastal stabilization technologies, patented technologies and their associated actor-networks, have the capacity to instigate change in coastal systems with the patent serving as an intermediary, circulating between actors and helping to define the relation between them. In relation to the process of grounding innovation these patent intermediaries help communicate technical information to planning disciplines and coastal managers, informing praxis and

ultimately impacting real world sites as novel technologies are implemented as part of coastal development practices such as site-design and infrastructure planning.

Professional praxis provides a vital linchpin in testing, evaluation, and implementation of innovative coastal technologies into actionable projects. As is discussed comprehensively in chapter 6, the Y02A serves as an anticipatory framework for management of sequential

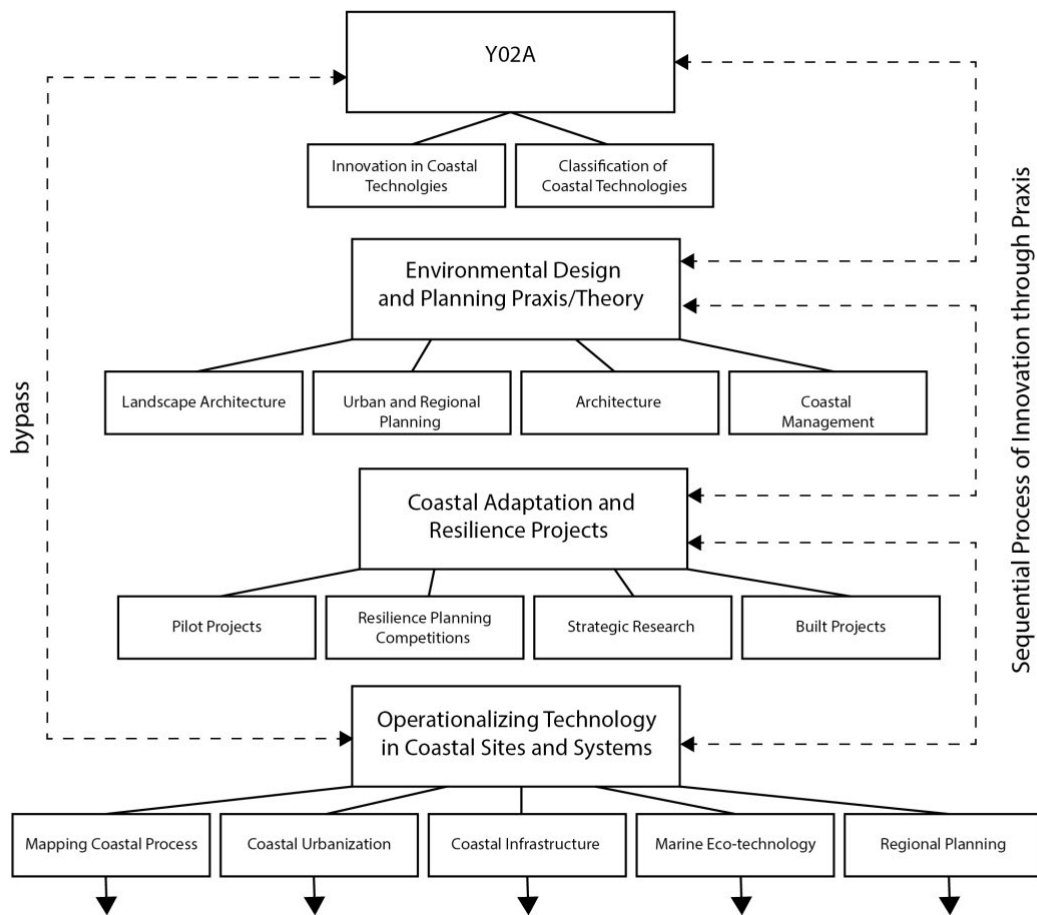


Figure 69: A schematic diagram linking the practices of design and planning to the Y02A classification scheme. (By Author)

innovation in environmental technology, informing a range of near-term and long-term planning processes. As such, integration of the Y02A with environmental planning and design praxis will inform this process across a range of interrelated planning activities, including the pragmatics of planning for probable and plausible futures as well as establish target benchmarks for pluralistic, and performative coastal futures by building the pathways to achieve these goals. The tangible benefits of this information exchange and workflow are easy to identify. For example, coastal adaptation and resilience planning competitions are an important mechanism for the diffusion of

innovation. Integrating innovation studies, and innovative technologies, into the competition process through the Y02A scheme can help inform design teams, governments, and community members, of the technological pathways available and indicate areas in need of further investment. Similar opportunities exist for the integration of Y02A innovations into novel research programs that bring together innovators, researchers, and the coastal/urban planning through pilot projects. The allied fields of environmental design and planning can enable the creation of these real-world experiments, bridging between theoretical, technical, and practical domains (figure 69). Collectively the process of grounding innovation aims to site and situate global sociotechnical process of Y02A adaptation technologies within the contingencies of coastal Anthromes. Environmental design and planning praxis is uniquely situated as mediator of this process given the allied field's capacity for integrating ecological process and environmental dynamics with social, urban, infrastructural systems. Expanding this capacity to integrate and inform coastal innovation operationalizes technical pathways for adaptation and resilience works.

Projecting Innovation

The projection of coastal adaptation and resilience technology involves the refinement of core technologies and the forward-looking conceptualization of technological frontiers. These projections of technical capacity, need, and trajectory, have the potential to consolidate innovation networks by compressing the distance between local, regional, and international coastal networks through focused innovation. As is documented in chapter 2, a diverse range of actors have the potential to instigate change in coastal systems and confront entrenched power systems utilizing the distinct agency of patented technology. In the context of climate change and sea-level rise, these expanded coastal actor-networks are integral to collective problem solving. The Y02A patent scheme is central to the consolidation of the resultant network space as it gathers, collates, and communicates technical knowledge, serving as not only intermediary between partners, agents, and adaptation efforts worldwide but also as knowledge infrastructure in support of systemic change. Projections of new technological frontiers also have the potential to build new networks by establishing partnerships with industries such as Artificial

Intelligence, environmental sensing, and additive manufacturing. The Y02A creates a robust framework to organize innovation in the coastal adaptation and resilience sector, focusing the projections of novel technology as they move between localized innovation networks and strategic global initiatives.

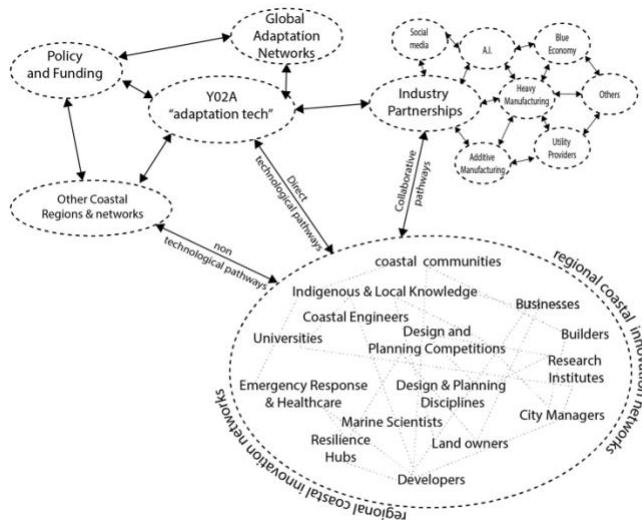


Figure 70: Diagram of the process of projecting innovations in which actor-networks involved in coastal adaptation and resilience works invent and share novel technologies build network capacity through the Y02A. (By Author)

Establishment of distinct classes of technology for artificial reefs, green infrastructure, environmental mapping and sensing, and river restoration etc. allows for inventors, institutions, professionals, governments, and community members to clearly identify areas of technology that they may contribute to, thus facilitating discovery and hastening innovation. Of course, creating new technology requires investment in research and

development, institutional partnerships, and core technologies and establishing technological frontiers in adaptation technology categories of the Y02A through partnerships between practitioners, research universities, industry, communities, and other actors in coastal networks. As is documented in case study chapter 5, these assemblages may facilitate the creation of novel forms of coastal infrastructure that are nimble, decentralized, and functionally hybrid, expanding the repertoire of coastal technology while building network capacity among partners.

Building network capacity through the projection of innovation helps identify key partners and establish future needs. Universities, professional organizations, allied environmental design and planning disciplines, coastal communities, and others in the regional adaptation and resilience networks are integral to defining the core technologies and future trends. Once these are identified, industry partners can help shape the contours of the field by contributing specific knowledge in the domains on artificial intelligence, heavy manufacturing, social media, and other

industry partners. The Y02A is integral to this process, helping to manage sequential innovation, providing inventors rights, and facilitating the diffusion of innovation in emergent sectors of technology (figure 70). The newly established subclasses of the Y02A will be foundational to defining technological capacity. For example, as new mapping and sensing technology are integrated with green infrastructural systems, the linkages between storm water management, flooding, and artificial intelligence, will build likely build smarter climate adaptive cities – a sector that will only expand as climate change continues.

The Y02A is strategically situated at the juncture between climate change, risk, and technology. Empirical studies on the relationship between climate change and innovation are also bringing these trajectories into dialogue, leading to new frameworks of “risk-mitigating innovation” that document the stimulating effect of natural disasters on technology and patent submission rates.⁴⁴³ Uptick in technological innovation responding to risk and climate change, and evolving range of pathways for implementing coastal adaptation and resilience efforts create a distinct opportunity for planners, designers, and engineers to integrate patent data and novel technologies into praxis. As planners, designers, and engineers, work on a diverse range of coastal projects and often integrate technology through infrastructure planning, modifications to land-use strategies, architecture, and open space systems they are logical partners in the effort to operationalize technological innovation in the coastal adaptation and resilience space. Obviously, a broader spectrum of technology converges in the coastal anthromes and must be considered in the context of coastal adaptation and resilience, including transportation, water, electricity, health, agriculture, and indirect technologies. These cross-sectoral technologies are well represented in the Y02A classification scheme and represent and expanding toolkit for coastal adaptation and resilience planning.

⁴⁴³ Miao and Popp, “Necessity as the Mother of Invention: Innovative Responses to Natural Disasters.”

Patents Referenced

- Boots, Edmund R. Artificial reef. US3888209A, filed November 14, 1973, and issued June 10, 1975.
- Bryan, John. System to Prevent the Overflowing of Rivers. US969334A, filed March 7, 1910, and issued September 6, 1910.
- Campbell, Matthew D., Robert L. Beine, and Steven G. Hall. Biologically-dominated artificial reef. United States US7144196B1, filed December 28, 2005, and issued December 5, 2006. <https://patents.google.com/patent/US7144196B1/en?q=7%2c144%2c196>.
- Ceglinski, Peter. Waste collection device. US10954642B2, filed December 6, 2017, and issued March 23, 2021.
- Cutler, Benjamin F., Norman Ashton Whitaker, Spencer G. Fowers, and Jeffrey Alex Kramer. Artificial reef datacenter. US10524395B2, filed May 27, 2016, and issued December 31, 2019.
- Darius, Alan Martin, Childs Martin Elizabeth, Cook John, and Alan Cook Geoffrey. Method apparatus and system for controlling fish. GB2567452A, filed October 12, 2017, and issued April 17, 2019.
- Edison, thomas. Electrical Distribution System. US263142, filed 1882, and issued August 22, 1882.
- Finkel, Shimrit, and Ido Sella. Methods and matrices for promoting fauna and flora growth. US9538732B2, filed February 13, 2014, and issued January 10, 2017.
- Gagliano, Sherwood M., and Mark H. Gagliano. Method and apparatus for growing oyster reef. US5269254A, filed July 6, 1992, and issued December 14, 1993.
- Garrett, William L. Synthetic seaweed. US4221500A, filed January 26, 1979, and issued September 9, 1980.
- Gray, Luke, and Alexander Slocum. Retrofitting Small Watercraft as Collection Boats for Sargassum Seaweed. United States US20230082558A1, filed February 12, 2021, and issued March 16, 2023.
- Han, Ji Ho. artificial fishing banks. KR102042054B1, filed March 22, 2019, and issued November 7, 2019.
- Henderson, D. Gregory. Self-adjusting floating environment (SAFE) system for earthquake and flood protection. US10711478B2, filed April 18, 2019, and issued July 14, 2020.
- Higa, Kiyoshi. Waste Tire Fishing Bank. JP2006180799A, filed December 28, 2004, and issued July 13, 2006.
- Holmberg, Dick L. Erosion control foundation mat and method. US4889446A, filed December 22, 1986, and issued December 26, 1989.
- Hulsemann, Jobst. Breakwater system. US4006598A, filed November 24, 1975, and issued February 8, 1977.
- Ianell, Allan W. Bionic dunes. US5104258A, filed June 21, 1991, and issued April 14, 1992.
- Ishida, Shinichi, Takatsugu Kawano, and Chiaki Sato. Artificial Refuge Reef for Fish. US3561402A, filed November 20, 1968, and issued February 9, 1971.
- james, Mitchell. Hedge. US380450, filed 1888, and issued April 3, 1888.
- Jung, in Ki. Artificial Fishing Banks Using Scrap Tires. KR20160076101A, filed December 22, 2014, and issued June 30, 2016.

Kania, Bruce G., Leslie M. Wiser, David L. Zimmerman, Alfred Cunningham, Frank M. Stewart, Russell F. Smith, and Thomas N. Coleman. Super-enhanced aquatic floating island plant habitat. US2005183331A1, filed July 1, 2004, and issued August 25, 2005.

Kito, Makoto, Takeshi Kimura, Yasushi Makihara, Takeshi Gonda, and Yoshio Suzuki. Artificial Shore Reef. JP2002000112A, filed June 26, 2000, and issued January 8, 2002.

Klose, Shelly. System and method for detecting objects in images. US11120557B1, filed February 10, 2021, and issued September 14, 2021.

Komiya, Kazuhiro. Hardened Material for Creating Seaweed Bed. JP2010104362A, filed September 9, 2009, and issued May 13, 2010.

Langdon, Brian B., Kenneth a Preston, and Thomas E. Coultas. System and method of dewatering dredge spoils using sloping drain barge. US2006162195A1, filed January 26, 2005, and issued July 27, 2006.

Mas, Sole Javier, and Rodriguez Gregorio Iglesias. Wave energy capture system by means of compressed air storage in depth (Machine-translation by Google Translate, not legally binding). ES2398121A1, filed November 27, 2012, and issued March 13, 2013.

Meinig, Christian, Scott E. Stalin, Alex I. Nakamura, and Hugh B. Milburn. System for reporting high resolution ocean pressures in near realtime for the purpose of Tsunami monitoring. US7289907B2, filed May 20, 2005, and issued October 30, 2007.

Mills, James Andrew, and Gregory Allan Parrent. Fluid fillable structure. US9297133B2, filed September 5, 2014, and issued March 29, 2016.

Moran, Dennis R., Walter C. Trnka, and Hans De Bruijn. Inclined plates for CSO. US9695584B2, filed October 24, 2013, and issued July 4, 2017.

Mouton, William J., Robert Grush, and Dolores B. Alton. Wave actuated coastal erosion reversal system for shorelines. US4998844A, filed January 30, 1990, and issued March 12, 1991.

Muench, Jr August A. Apparatus and method for marine habitat development. US5007377A, filed February 6, 1990, and issued April 16, 1991.

Nero, Ingvar. Water barrier foot element, a water barrier shield support element, a water barrier shield system and a method for manufacturing a water barrier foot element. US10458084B2, filed September 13, 2016, and issued October 29, 2019.

Op, Den Velde Jan, Jan B. Elzerman, and Klaas Oterdoom. Method of constructing an artificial island and island constructed by the same. US4397587A, filed October 6, 1980, and issued August 9, 1983.

Ortego, Tyler R., Robert L. Beine, Steven G. Hall, and Matthew D. Campbell. Artificial material conducive to attract and grow oysters, mollusks or other productive and/or stabilizing organisms. US8312843B2, filed June 30, 2006, and issued November 20, 2012.

Ortego, Tyler R., and Matthew D. Campbell. Mature modular reef. US9144228B1, filed March 24, 2014, and issued September 29, 2015.

Pereira, De Gouveia Lopes De Almeida José Paulo. Artificial coastal-protection reef with energy generation unit with or without direct contact with seawater. US10233894B2, filed November 11, 2014, and issued March 19, 2019.

Philips, William E. Method for building levees. US1980634A, filed November 14, 1932, and issued November 13, 1934.

Pierce, Jr Webster. Wave suppressor and sediment collection system. US8226325B1, filed October 9, 2009, and issued July 24, 2012.

Piernavieja, Izquierdo Gonzalo, Dominguez Tomas Espino, Suarez Baltasar Penate, and Alamo Daniel Henriquez. Sistema De Desalacion Por Osmosis Inversa Alimentado Por Energia Solar. ES2299396B1, filed December 21, 2004, and issued April 1, 2009.

Pyman, Robert James, Richard William Thomson, and Darren Geoffrey Dunn. Improvements to Multifunction Solar Utility Panels. AU2019312560B2, filed September 25, 2019, and issued December 10, 2020.

Riet, Keith Van de, Jason Vollen, and Anna Dyson. Method and apparatus for coastline remediation, energy generation, and vegetation support. United States US8511936B2, filed November 30, 2011, and issued August 20, 2013.

Sella, Ido, Shimrit Finkel, and Adi Neuman. Tide pool. USD841185S, filed July 11, 2017, and issued February 19, 2019.

Sella, Ido, and Barak Saar. Interlocking Ecological Armoring Units and Uses Thereof in Forming a Costal Barrier. US2023073789A1, filed February 25, 2021, and issued March 9, 2023.

Slat, Boyan Damir, Sjoerd Drenkelford, Jan-Willem Damsteeg, Berkel E/V Damsteeg Selma Van, Berk Hendrikus Van, Ian Matthew Smith, and Middendorp Matthias Van. A Free-Flowing Water Cleaning System. WO2020218926A1, filed April 28, 2020, and issued October 29, 2020.

Suzuki, Tetsuo. Algal culturing reef unit, artificial reef unit and artificial culturing and fishing field unit. US4508057A, filed September 16, 1983, and issued April 2, 1985.

———. Concrete blocks for use underwater for algal culture. EP0134855A1, filed September 15, 1983, and issued March 27, 1985.

Tiballi, Christine. Systems and methods of urban rooftop agriculture with smart city data integration. AU2021344973A1, filed September 16, 2021, and issued March 30, 2023.

Tyagi, Sunit. System and Method for Reducing Temperature of Water in Coral Reef and Adjacent Ocean. WO2022091107A1, filed December 24, 2020, and issued May 5, 2022.

Walter, David M. Concrete and tire artificial reef. US6042300A, filed December 29, 1998, and issued March 28, 2000.

Ward, Marc. Marine microplastic removal tool. US8944253B2, filed November 21, 2013, and issued February 3, 2015.

William, John Douglas Bateman, Gonzalez Olias Dolores, and Bernardo Udelman Leon Samuel. Artificial reef for coastal protection. GB2610697A, filed July 15, 2022, and issued March 15, 2023.

Zoet, Francis Rosita Agnes, Max Philip Thomas Ehrhorn, Anne Marieke Eveleens, and Saskia Studer. Watercourse Provided with a Bubble Screen, and Bubble Screen Therefore. WO2021075962A1, filed October 14, 2020, and issued April 22, 2021.

Bibliography

- Abbas, Assad, Limin Zhang, and Samee U Khan. "A Literature Review on the State-of-the-Art in Patent Analysis." *World Patent Information* 37 (2014): 3–13.
- Abreu, David Perez, Karima Velasquez, Marilia Curado, and Edmundo Monteiro. "A Resilient Internet of Things Architecture for Smart Cities." *Annals of Telecommunications* 72, no. 1–2 (2017): 19–30.
- Acuto, Michele. "The New Climate Leaders?" *Review of International Studies* 39, no. 4 (2013): 835–57.
- Adger, W Neil, Terry P Hughes, Carl Folke, Stephen R Carpenter, and Johan Rockström. "Social-Ecological Resilience to Coastal Disasters." *Science* 309, no. 5737 (2005): 1036–39.
- Ahmed, Farah, Daniel Johnson, Raed Hashaikeh, and Nidal Hilal. "Barriers to Innovation in Water Treatment." *Water* 15, no. 4 (2023): 773.
- Ahn, Sang-Jin, and Ho Young Yoon. "'Green Chasm' in Clean-Tech for Air Pollution: Patent Evidence of a Long Innovation Cycle and a Technological Level Gap." *Journal of Cleaner Production* 272 (2020): 122726.
- Airoidi, Laura, Xavier Turon, Shimrit Perkol-Finkel, and Marc Rius. "Corridors for Aliens but Not for Natives: Effects of Marine Urban Sprawl at a Regional Scale." *Diversity and Distributions* 21, no. 7 (2015): 755–68.
- Ajami, Newsha K, Barton H Thompson Jr, and David G Victor. "The Path to Water Innovation." *Woods Institute for the Environment, Stanford, Working Paper*, 2014.
- Akhter, Shume, M Hasan, and ZH Khan. "Impact of Climate Change on Saltwater Intrusion in the Coastal Area of Bangladesh," 20–24, 2012.
- "Algorithm for Automated Sargassum Detection for Landsat-8 OLI Imagery(SSC-00505) | NASA Software Catalog." Accessed May 3, 2023. <https://software.nasa.gov/software/SSC-00505>.
- Almeida, JPPG Lopes de, JRCB Abrantes, and JGSES Bento. "A Simplified Model for Expedient Computational Assessment of the Novel REEFS Wave Energy Converter Power Output." *Renewable Energy* 157 (2020): 43–54.
- Almeida, JPPG Lopes de, B Mujtaba, and AM Oliveira Fernandes. "Preliminary Laboratorial Determination of the REEFS Novel Wave Energy Converter Power Output." *Renewable Energy* 122 (2018): 654–64.
- Altwies, Joy E, and Gregory F Nemet. "Innovation in the US Building Sector: An Assessment of Patent Citations in Building Energy Control Technology." *Energy Policy* 52 (2013): 819–31.
- Alvial-Palavicino, Carla. "The Future as Practice. A Framework to Understand Anticipation in Science and Technology." *TECNOSCIENZA: Italian Journal of Science & Technology Studies* 6, no. 2 (2016): 135–72.
- Ambec, Stefan, and Philippe Barla. "A Theoretical Foundation of the Porter Hypothesis." *Economics Letters* 75, no. 3 (2002): 355–60.
- Andrews, R N L. *Managing the Environment, Managing Ourselves: A History of American Environmental Policy*. Yale University Press, 1999.
- Angelucci, Stefano, F Javier Hurtado-Albir, and Alessia Volpe. "Supporting Global Initiatives on Climate Change: The EPO's 'Y02-Y04S' Tagging Scheme." *World Patent Information* 54 (2018): S85–92.

- ArcGIS StoryMaps. "Water Atlas," April 14, 2020.
<https://storymaps.arcgis.com/stories/808093e2f9ce402db1a837027ca05a5e>.
- Arthur, W Brian. "The Structure of Invention." *Research Policy* 36, no. 2 (2007): 274–87.
- Attems, Marie-Sophie, Thomas Thaler, Elisabetta Genovese, and Sven Fuchs. "Implementation of Property-level Flood Risk Adaptation (PLFRA) Measures: Choices and Decisions." *Wiley Interdisciplinary Reviews: Water* 7, no. 1 (2020): e1404.
- Azam, M Monirul. "Climate Change Resilience and Technology Transfer: The Role of Intellectual Property." *Nordic Journal of International Law* 80, no. 4 (2011): 485–505.
- Badger, Emily. "Tech Envisions the Ultimate Start-Up: An Entire City." *The New York Times*, February 24, 2018, sec. The Upshot. <https://www.nytimes.com/2018/02/24/upshot/tech-envisions-the-ultimate-start-up-an-entire-city.html>.
- Bailey, MF. "History of Classification of Patents." *J. Pat. Off. Soc'y* 28 (1946): 463.
- Basar, Asiful. "Water Security in Coastal Region of Bangladesh: Would Desalination Be a Solution to the Vulnerable Communities of the Sundarbans?" *Bangladesh E-Journal of Sociology* 9, no. 2 (2012): 31.
- Bathelt, Harald, Maryann Feldman, and Dieter F Kogler. *Beyond Territory: Dynamic Geographies of Innovation and Knowledge Creation*. Routledge, 2012.
- Batty, Michael, Kay W Axhausen, Fosca Giannotti, Alexei Pozdnoukhov, Armando Bazzani, Monica Wachowicz, Georgios Ouzounis, and Yuval Portugali. "Smart Cities of the Future." *The European Physical Journal Special Topics* 214 (2012): 481–518.
- Bay Area: Resilient By Design Challenge. "Bay Area: Resilient By Design Challenge." Accessed June 21, 2021. <http://www.resilientbayarea.org>.
- Beatley, Timothy. *Blue urbanism: exploring connections between cities and oceans*. Washington, DC: Island Press, 2014.
- Bechtold, Stefan, Christopher Buccafusco, and Christopher Jon Sprigman. "Innovation Heuristics: Experiments on Sequential Creativity in Intellectual Property." *Ind. LJ* 91 (2015): 1251.
- Beck, Silke, and Martin Mahony. "The IPCC and the Politics of Anticipation." *Nature Climate Change* 7, no. 5 (2017): 311–13.
- Bel, Germà, and Stephan Joseph. "Climate Change Mitigation and the Role of Technological Change: Impact on Selected Headline Targets of Europe's 2020 Climate and Energy Package." *Renewable and Sustainable Energy Reviews* 82 (2018): 3798–3807.
- Bélanger, Pierre. "Landscape as Infrastructure." *Landscape Journal* 28, no. 1 (2009): 79–95.
 ———. *Landscape as Infrastructure: A Base Primer*. Routledge, 2016.
- Belfanti, Carlo. "Guilds, Patents, and the Circulation of Technical Knowledge: Northern Italy during the Early Modern Age." *Technology and Culture* 45, no. 3 (2004): 569–89.
- Berger, Alan M, Michael Wilson, Jonah Susskind, and Richard J Zeckhauser. "Theorizing the Resilience District: Design-Based Decision Making for Coastal Climate Change Adaptation." *Journal of Landscape Architecture* 15, no. 1 (2020): 6–17.
- Bergillos, Rafael J, Cristobal Rodriguez-Delgado, James Allen, and Gregorio Iglesias. "Wave Energy Converter Configuration in Dual Wave Farms." *Ocean Engineering* 178 (2019): 204–14.
- Bergillos, Rafael J, Cristobal Rodriguez-Delgado, and Gregorio Iglesias. *Ocean Energy and Coastal Protection: A Novel Strategy for Coastal Management Under Climate Change*. Springer, 2020.

- BERKEL, Klaas van. "Cornelius Meijer Inventor et Fecit': On the Representation of Science in Late Seventeenth-Century Rome," 2002.
- Bernard, Eddie N, and Christian Meinig. "History and Future of Deep-Ocean Tsunami Measurements," 1–7. IEEE, 2011.
- Berveglieri, Roberto. *Le Vie Di Venezia: Canali Lagunari e Rii a Venezia: Inventori, Brevetti, Tecnologia e Legislazione Nei Secoli XIII-XVIII*. Cierre, 1999.
- Biagini, Bonizella, Laura Kuhl, Kelly Sims Gallagher, and Claudia Ortiz. "Technology Transfer for Adaptation." *Nature Climate Change* 4, no. 9 (2014): 828–34.
- Biagioli, Mario. "From Print to Patents: Living on Instruments in Early Modern Europe." *History of Science* 44, no. 2 (2006): 139–86.
- . "Patent Republic: Representing Inventions, Constructing Rights and Authors." *Social Research*, 2006, 1129–72.
- . "Patent Specification and Political Representation: How Patents Became Rights." *Making and Unmaking Intellectual Property: Creative Production in Legal and Cultural Perspective*, 2011, 25–40.
- Biagioli, Mario, Peter Jaszi, and Martha Woodmansee. *Making and Unmaking Intellectual Property: Creative Production in Legal and Cultural Perspective*. University of Chicago Press, 2015.
- Birch, Traci, and Jeff Carney. "Delta Urbanism: Aligning Adaptation with the Protection and Restoration Paradigm in Coastal Louisiana." *Technology| Architecture+ Design* 3, no. 1 (2019): 102–14.
- . "Regional resilience: building adaptive capacity and community well-being across louisiana's dynamic coastal-inland continuum." *Louisiana's Response to Extreme Weather: A Coastal State's Adaptation Challenges and Successes* (2020): 313-340.
- Bishop, Melanie J, Mariana Mayer-Pinto, Laura Airoidi, Louise B Firth, Rebecca L Morris, Lynette HL Loke, Stephen J Hawkins, Larissa A Naylor, Ross A Coleman, and Su Yin Chee. "Effects of Ocean Sprawl on Ecological Connectivity: Impacts and Solutions." *Journal of Experimental Marine Biology and Ecology* 492 (2017): 7–30.
- Bloomberg.com*. "Reviving New York Harbor With Oysters: Why Hasn't This Happened Yet?" September 11, 2012. <https://www.bloomberg.com/news/articles/2012-09-11/reviving-new-york-harbor-with-oysters-why-hasn-t-this-happened-yet>.
- Blount, Craig, Valeriya Komyakova, Lachlan Barnes, Marcus Lincoln Smith, Dilys Zhang, Kate Reeds, Daryl McPhee, Matthew D Taylor, William Macbeth, and Evan Needham. "Using Ecological Evidence to Refine Approaches to Deploying Offshore Artificial Reefs for Recreational Fisheries." *Bulletin of Marine Science* 97, no. 4 (2021): 665–98.
- BondGraham, Darwin. "The New Orleans That Race Built: Racism, Disaster, and Urban Spatial Relationships." *Souls* 9, no. 1 (2007): 4–18.
- Booher, David E, and Judith E Innes. "Network Power in Collaborative Planning." *Journal of Planning Education and Research* 21, no. 3 (2002): 221–36.
- Bott, Lisa-Michele, and Boris Braun. "How Do Households Respond to Coastal Hazards? A Framework for Accommodating Strategies Using the Example of Semarang Bay, Indonesia." *International Journal of Disaster Risk Reduction* 37 (2019): 101177.
- Bosselmann, Peter C. *Adaptations of the metropolitan landscape in Delta Regions*. Routledge, 2018.

- Boyd, Emily, Björn Nykvist, Sara Borgström, and Izabela A Stacewicz. "Anticipatory Governance for Social-Ecological Resilience." *Ambio* 44, no. 1 (2015): 149–61.
- Brockman, Joy R. "Coastal Ecosystem Protection in Florida." *Nova L. Rev.* 20 (1995): 859.
- Buchanan, Ben. "Unlocking the Value of Patent Data: Patent Informatics Services at the UK Intellectual Property Office (UK-IPO)." *World Patent Information* 30, no. 4 (2008): 335–37.
- Byrum, Matthew. *Optimizing Bioengineered Coastal Materials*. Louisiana State University and Agricultural & Mechanical College, 2014.
- Cain, Mary, and Robert Mittman. "Diffusion of Innovation in Health Care," 2002.
- Caldarice, Ombretta, Grazia Brunetta, and Nicola Tollin. "The Challenge of Urban Resilience: Operationalization." In *Urban Resilience for Risk and Adaptation Governance*, 1–6. Springer, 2019.
- Calel, Raphael. "Adopt or Innovate: Understanding Technological Responses to Cap-and-Trade." *American Economic Journal: Economic Policy* 12, no. 3 (2020): 170–201.
- Campbell, Matthew D., Robert L. Beine, and Steven G. Hall. Biologically-dominated artificial reef. United States US7144196B1, filed December 28, 2005, and issued December 5, 2006.
- Campbell, Matthew Dwain. *Analysis and Evaluation of a Bioengineered Submerged Breakwater*. Louisiana State University and Agricultural & Mechanical College, 2004.
- Campbell, Matthew Dwain, Tyler Ray Ortego, Robert Leon Beine, and Steven G. Hall. Three-dimensional printing. United States US9962855B2, filed September 13, 2016, and issued May 8, 2018..
- Cantrell, Bradley, Laura J Martin, and Erle C Ellis. "Designing Autonomy: Opportunities for New Wildness in the Anthropocene." *Trends in Ecology & Evolution* 32, no. 3 (2017): 156–66.
- Carlisle Jr, John G, Charles H Turner, and Earl E Ebert. "Fish Bulletin 124. Artificial Habitat in the Marine Environment," 1963.
- Carral, Luis, Carolina Camba Fabal, M^a Isabel Lamas Galdo, M^a Jesús Rodríguez-Guerreiro, and Juan José Cartelle Barros. "Assessment of the Materials Employed in Green Artificial Reefs for the Galician Estuaries in Terms of Circular Economy." *International Journal of Environmental Research and Public Health* 17, no. 23 (2020): 8850.
- Chang, Shann-Bin. "Using Patent Analysis to Establish Technological Position: Two Different Strategic Approaches." *Technological Forecasting and Social Change* 79, no. 1 (2012): 3–15.
- Chapman, M G, D Blockley, J People, and B Clynick. "Effect of Urban Structures on Diversity of Marine Species." *Ecology of Cities and Towns: A Comparative Approach*. Cambridge University Press, Cambridge, 2009.
- Chavez, Anthony E. "Exclusive Rights to Saving the Planet: The Parenting of Geoengineering Inventions." *Nw. J. Tech. & Intell. Prop.* 13 (2015): 1.
- Chen, Ping, Chao-Kai Kang, and Jin-Li Yu. "Marine Life and Coastal Restoration by Utilizing Steel Slag to Create Sea Forest on Sandy Coast of Southwest Taiwan," 1–4. IEEE, 2019.
- Chen, Rain. "Design Patent Map Visualization Display." *Expert Systems with Applications* 36, no. 10 (2009): 12362–74.
- Chesbrough, H.W. *Open Innovation: The New Imperative for Creating and Profiting from Technology*. G - Reference, Information and Interdisciplinary Subjects Series. Harvard Business School Press, 2003.

- Cho, Sunyoung, Lars Mathiassen, and Michael Gallivan. "Crossing the Diffusion Chasm: From Invention to Penetration of a Telehealth Innovation." *Information Technology & People*, 2009.
- Ciriaco, Salvatore. *Building on Water : Venice, Holland and the Construction of the European Landscape in Early Modern Times*. New York, N.Y. ; Oxford: Berghahn Books, 2006.
- Cockburn, Iain M, Rebecca Henderson, and Scott Stern. 4. *The Impact of Artificial Intelligence on Innovation: An Exploratory Analysis*. University of Chicago Press, 2019.
- Comfort, Louise K. "Cities at Risk: Hurricane Katrina and the Drowning of New Orleans." *Urban Affairs Review* 41, no. 4 (2006): 501–16.
- Company, Tampa Publishing. "Sowing the Seeds of Life." Tampa Bay Times. Accessed September 17, 2021. <https://www.tampabay.com/archive/1990/10/28/sowing-the-seeds-of-life/>.
- Court, United States. Supreme, and W P Company. *Supreme Court Reporter: U.S. Reports. Cases Argued and Determined in the Supreme Court of the United States*. West publishing Company, 1922.
- Dahlgren, Eric, Caner Göçmen, Klaus Lackner, and Garrett Van Ryzin. "Small Modular Infrastructure." *The Engineering Economist* 58, no. 4 (2013): 231–64.
- Daly, Shanna R, Seda Yilmaz, James L Christian, Colleen M Seifert, and Richard Gonzalez. "Design Heuristics in Engineering Concept Generation," 2012.
- Davidson, Julie L, Chris Jacobson, Anna Lyth, Aysin Dedekorkut-Howes, Claudia L Baldwin, Joanna C Ellison, Neil J Holbrook, Michael J Howes, Silvia Serrao-Neumann, and Lila Singh-Peterson. "Interrogating Resilience: Toward a Typology to Improve Its Operationalization." *Ecology and Society* 21, no. 2 (2016).
- De Almeida, JPPG Lopes. "REEFS: An Artificial Reef for Wave Energy Harnessing and Shore Protection—A New Concept towards Multipurpose Sustainable Solutions." *Renewable Energy* 114 (2017): 817–29.
- De Barbieri, Edward W. "Urban Anticipatory Governance." *Fla. St. UL Rev.* 46 (2018): 75.
- de Graaf-van Dinther, Rutger, and Henk Ovink. "The five pillars of climate resilience." *Climate Resilient Urban Areas: Governance, design and development in coastal delta cities* (2021): 1-19.
- Dechezlepretre, Antoine, Sam Fankhauser, Matthieu Glachant, Jan Stoeber, and Simon Touboul. "Invention and Global Diffusion of Technologies for Climate Change Adaptation," 2020.
- "Desrochers_et_al_2020_sargassum_uses_guide_advance.Pdf." Accessed May 3, 2023. https://www.cavehill.uwi.edu/cermes/projects/sargassum/docs/desrochers_et_al_2020_sargassum_uses_guide_advance.aspx.
- Dhoble, Yogesh Nathuji, and Sirajuddin Ahmed. "Review on the Innovative Uses of Steel Slag for Waste Minimization." *Journal of Material Cycles and Waste Management* 20 (2018): 1373–82.
- "DirtSat | Green Roof Marketplace for Urban Sustainability." Accessed June 21, 2023. <https://www.dirtsat.com/>.
- Djakouré, Sandrine, Moacyr Araujo, Aubains Hounsou-Gbo, Carlos Noriega, and Bernard Bourlès. "On the Potential Causes of the Recent Pelagic Sargassum Blooms Events in the Tropical North Atlantic Ocean." *Biogeosciences Discussions*, 2017, 1–20.

- Dube, Cinderella, and Victor Gumbo. "Diffusion of Innovation and the Technology Adoption Curve: Where Are We? The Zimbabwean Experience." *Business and Management Studies* 3, no. 3 (2017): 34.
- Eads, James Buchanan, Joseph Meredith Toner Collection (Library of Congress), and YA Pamphlet Collection (Library of Congress). *Mouth of the Mississippi. Jetty System Explained*. St. Louis: Times Print, 1874.
- Eads, James Buchanan, and Estill McHenry. *Addresses and Papers of James B. Eads, Together with a Biographical Sketch*. St. Louis: Slawson & Co., printers, 1884.
- Edwards, Paul N. *A Vast Machine : Computer Models, Climate Data, and the Politics of Global Warming*. Cambridge, Mass.: MIT Press, 2010.
- Edwards, Paul N. "Knowledge Infrastructures for the Anthropocene." *The Anthropocene Review* 4, no. 1 (2017): 34–43.
- Elgort, Irina. "E-Learning Adoption: Bridging the Chasm," 181–85, 2005.
- Fabi, Gianna, Alessandra Spagnolo, Denise Bellan-Santini, Eric Charbonnel, Burak Ali Çiçek, Juan J Goutayer García, Antony C Jensen, Argiris Kallianiotis, and Miguel Neves dos Santos. "Overview on Artificial Reefs in Europe." *Brazilian Journal of Oceanography* 59 (2011): 155–66.
- Facebook, Twitter, Show more sharing options, Facebook, Twitter, LinkedIn, Email, Copy Link URLCopied!, and Print. "Beach Erosion Engineer Called a Godsend, Fake." Los Angeles Times, September 10, 1989. <https://www.latimes.com/archives/la-xpm-1989-09-10-mn-2578-story.html>.
- Factory and Industrial Management*. McGraw-Hill publishing Company, Incorporated, 1900.
- Falck, Carsten, Markus Ramatschi, Mitja Bartsch, and Alexander Merx. "The GNSS-Based Component of the German-Indonesian Tsunami Early Warning System (GITEWS): Overview, First Operation Results and Current Developments," 134–37. IEEE, 2010.
- Feldman, Maryann P, and Richard Florida. "The Geographic Sources of Innovation: Technological Infrastructure and Product Innovation in the United States." *Annals of the Association of American Geographers* 84, no. 2 (1994): 210–29.
- Ferguson, Eugene S. *Engineering and the Mind's Eye*. Cambridge, Mass.: MIT Press, 1993.
- Fernandez, Hernan, Gregorio Iglesias, Rodrigo Carballo, Alberte Castro, Marcos Sánchez, and Francisco Taveira-Pinto. "Optimization of the Wavecat Wave Energy Converter." *Coastal Engineering Proceedings*, no. 33 (2012): 5–5.
- Ferro-Azcona, Hakna, Alejandro Espinoza-Tenorio, Rafael Calderón-Contreras, Victoria C Ramenzoni, Maria de las Mercedes Gómez País, and Maria Azahara Mesa-Jurado. "Adaptive Capacity and Social-Ecological Resilience of Coastal Areas: A Systematic Review." *Ocean & Coastal Management* 173 (2019): 36–51.
- Fikes, R. "Artificial Reefs of the Gulf of Mexico: A Review of Gulf State Programs & Key Considerations." *National Wildlife Federation*, 2013, 22.
- Fitzhardinge, R C, and J H Bailey-Brock. "Colonization of Artificial Reef Materials by Corals and Other Sessile Organisms." *Bulletin of Marine Science* 44, no. 2 (1989): 567–79.
- Fleming, Billy. "'Rebuild by Design' in New York City: Investigating the Competition Process and Discussing Its Outcomes." *Ri-Vista. Research for Landscape Architecture* 15, no. 2 (2017): 200–215.

- Fleming, Lee, and Olav Sorenson. "Technology as a Complex Adaptive System: Evidence from Patent Data." *Research Policy* 30, no. 7 (2001): 1019–39.
- "Flood and Coastal Defences," n.d., 24.
- Foley, Rider W, D Guston, and Daniel Sarewitz. "Towards the Anticipatory Governance of Geoengineering." *Geoengineering Our Climate*, 2015.
- Folpp, Heath R, Hayden T Schilling, Graeme F Clark, Michael B Lowry, Ben Maslen, Marcus Gregson, and Iain M Suthers. "Artificial Reefs Increase Fish Abundance in Habitat-limited Estuaries." *Journal of Applied Ecology* 57, no. 9 (2020): 1752–61.
- Forman, James William. "Generalized Monitoring of 'SEASCAPE' Installation at Cape Hatteras Lighthouse, North Carolina," 1986.
- French, P.W. *Coastal Defences: Processes, Problems and Solutions*. Taylor & Francis, 2002.
- Fuerth, Leon. "Operationalizing Anticipatory Governance." *Prism* 2, no. 4 (2011): 31–46.
- Fuller, Buckminster R. *Inventions: The Patented Works of Buckminster Fuller*. New York: St. Martins Press, 1983.
- Fuller, R.B. *Operating Manual for Spaceship Earth*. A Clarion Book. Southern Illinois University.
- Gabrielsson, Jonas, Diamanto Politis, Kenneth M Persson, and Johan Kronholm. "Promoting Water-Related Innovation through Networked Acceleration: Insights from the Water Innovation Accelerator." *Journal of Cleaner Production* 171 (2018): S130–39.
- Gagliano, Sherwood M, and Johannes L Van Beek. *Geologic and Geomorphic Aspects of Deltaic Processes, Mississippi Delta System*. Coastal Resources Unit, Center for Wetland Resources, Louisiana State University, 1970.
- Gaul, G.M. *The Geography of Risk: Epic Storms, Rising Seas, and the Cost of America's Coasts*. Farrar, Straus and Giroux, 2019.
- Gherardi, Silvia, and Davide Nicolini. "Actor-Networks: Ecology and Entrepreneurs," n.d.
- Giedion Sigfried. *Mechanization Takes Command a Contribution to Anonymous History*. Oxford Univ. Press 1948.
- Glavovic, Bruce C. "Coastal Innovation Imperative." *Sustainability* 5, no. 3 (2013): 934–54.
- . "Coastal Innovation Paradox." *Sustainability* 5, no. 3 (2013): 912–33.
- Glavovic, Bruce, et al., eds. *Climate change and the coast: building resilient communities*. CRC Press, 2014.
- Goldburg, Rebecca, and Rosamond Naylor. "Future Seascapes, Fishing, and Fish Farming." *Frontiers in Ecology and the Environment* 3, no. 1 (2005): 21–28.
- Goodman, Alan H, and Thomas L Leatherman. "Traversing the Chasm between Biology." *Building a New Biocultural Synthesis: Political-Economic Perspectives on Human Biology*, 1998, 1.
- Grabowski, Henry G, Joseph A DiMasi, and Genia Long. "The Roles of Patents and Research and Development Incentives in Biopharmaceutical Innovation." *Health Affairs* 34, no. 2 (2015): 302–10.
- Gregotti, Vittorio (Editor) 46 Rassegna (Patent and Design) - Quarterly year XIII, 46/2 June 1991
- Griggs, Gary B. "The Effects of Armoring Shorelines—the California Experience." In *Puget Sound Shorelines and the Impacts of Armoring—Proceedings of a State of the Science Workshop*, 77–84, 2009.
- Grosshuesch, Kelly. "Solving the First Mile/Last Mile Problem: Electric Scooters and Dockless Bicycles Are Positioned to Provide Relief to Commuters Struggling with a Daily Commute." *Wm. & Mary Env'tl. L. & Pol'y Rev.* 44 (2019): 847.

- Grove, Robert S, Makoto Nakamura, Hiroshi Kakimoto, and Choule J Sonu. "Aquatic Habitat Technology Innovation in Japan." *Bulletin of Marine Science* 55, no. 2–3 (1994): 276–94.
- Gu, Roy R. "Beneficial Reuses of Scrap Tires in Hydraulic Engineering." *Water Pollution: Environmental Impact Assessment of Recycled Wastes on Surface and Ground Waters*, 2005, 183–215.
- Guerzoni, Marco, T Taylor Aldridge, David B Audretsch, and Sameeksha Desai. "A New Industry Creation and Originality: Insight from the Funding Sources of University Patents." In *Universities and the Entrepreneurial Ecosystem*. Edward Elgar Publishing, 2017.
- Gupta, Aarti, Ina Möller, Frank Biermann, Sikina Jinnah, Prakash Kashwan, Vikrom Mathur, David R Morrow, and Simon Nicholson. "Anticipatory Governance of Solar Geoengineering: Conflicting Visions of the Future and Their Links to Governance Proposals." *Current Opinion in Environmental Sustainability* 45 (2020): 10–19.
- Guston, David H. "Understanding 'Anticipatory Governance.'" *Social Studies of Science* 44, no. 2 (2014): 218–42.
- Halevy, Alon Y, Oren Etzioni, AnHai Doan, Zachary G Ives, Jayant Madhavan, Luke K McDowell, and Igor Tatarinov. "Crossing the Structure Chasm.," 2003.
- Hall, Steven G, Robert Beine, Matthew Campbell, Tyler Ortego, and Jon D Risinger. "Growing Living Shorelines and Ecological Services via Coastal Bioengineering." In *Living Shorelines*, 249–70. CRC Press, 2017.
- Hall, Steven G, Matthew D Campbell, Tyler Ortego, and Robert Beine. "Growing Infrastructure: Entrepreneurial Thought and Action to Develop Coastal Bioengineering Technologies, From Education to Sustainable Production," 2019.
- Halle, Louise L, Annemette Palmqvist, Kristoffer Kampmann, and Farhan R Khan. "Ecotoxicology of Micronized Tire Rubber: Past, Present and Future Considerations." *Science of the Total Environment* 706 (2020): 135694.
- Hansen, Bernd, and Dirk Schüssler-Langeheine. *Patent Practice in Japan and Europe: Liber Amicorum for Guntram Rahn*. Kluwer Law International BV, 2011.
- Hansen, Brett. "Removing The Mississippi's Mud Lump: The Eads South Pass Navigation Works." *Civil Engineering Magazine Archive* 78, no. 10 (2008): 36–39.
- Hargadon, Andrew B, and Yellowlees Douglas. "When Innovations Meet Institutions: Edison and the Design of the Electric Light." *Administrative Science Quarterly* 46, no. 3 (2001): 476–501.
- Hartwell, SI, DM Jordahl, CEO Dawson, and AS Ives. "Toxicity of Scrap Tire Leachates in Estuarine Salinities: Are Tires Acceptable for Artificial Reefs?" *Transactions of the American Fisheries Society* 127, no. 5 (1998): 796–806.
- Haupt, Lewis. Jetty or breakwater., issued November 26, 1901.
- Haupt, Lewis M. Dike or breakwater. US380569, issued April 3, 1888.
- . "History of the Reaction Breakwater at Aransas Pass, Texas." *Journal of the Franklin Institute* 165, no. 2 (1908): 81–97.
- . "Scientific American: Supplement," Munn and Company, 1900.
- . "The Reaction Breakwater as Proposed for the Opening of the Southwest Pass of the Mississippi River." *Scientific American: Supplement*, August 18, 1900, 20604–6.

- Hayter, Christopher S, Einar Rasmussen, and Jacob H Rooksby. "Beyond Formal University Technology Transfer: Innovative Pathways for Knowledge Exchange." *The Journal of Technology Transfer* 45 (2020): 1–8.
- Helmers, Christian, and Mark Rogers. "Does Patenting Help High-Tech Start-Ups?" *Research Policy* 40, no. 7 (2011): 1016–27.
- Henry, Joseph. *Meteorology in Its Connection with Agriculture*. p. 455-492, 419-[552; 461]-524 incl. diags., illus.tables. [Washington, D. C., 1857.
- Hickling, Samuel, Jamie Matthews, and James Murphy. "The Suitability of Alkali Activated Slag as a Substrate for Sessile Epibenthos in Reef Cubes®." *Ecological Engineering* 174 (2022): 106471.
- Hills, Jeremy M, Evanthe Michalena, and Konstantinos J Chalvatzis. "Innovative Technology in the Pacific: Building Resilience for Vulnerable Communities." *Technological Forecasting and Social Change* 129 (2018): 16–26.
- Hindle, Richard L. "Levees That Might Have Been." *Places Journal*, 2015.
<https://placesjournal.org/article/levees-that-might-have-been/>.
- . "Prototyping the Mississippi Delta: Patents, Alternative Futures, and the Design of Complex Environmental Systems." *Journal of Landscape Architecture* 12, no. 02 (n.d.): 32–47. <https://doi.org/10.1080/18626033.2017.1361084>.
- . "A Vertical Garden: Origins of the Vegetation-Bearing Architectonic Structure and System (1938)." *Studies in the History of Gardens & Designed Landscapes* 32, no. 2 (2012): 99–110.
- . "Inventing Venice: An Urban and Environmental Innovation Model from the Lagoon City." *J. Pat. & Trademark Off. Soc'y* 100 (2018): 529.
- . "Patent Scenarios for the Mississippi River." *Journal of Architectural Education* 71, no. 2 (2017): 280–85.
- Hindle, Richard L, and Bhatia Neeraj. "Territorial Technologies," 2016.
- Hirschfeld, Daniella, Kristina E Hill, and Ellen Plane. "Adapting to Sea Level Rise: Insights from a New Evaluation Framework of Physical Design Projects." *Coastal Management* 49, no. 6 (2021): 636–61.
- Holly, J. Arthur. "FLOOD CONTROL DIFFICULTY; The Principal Trouble Believed to Be Political, Not Engineering." *The New York Times*, May 21, 1927,
- Holmberg, Dick. "Alternative to Traditional Ways of Treating Shoreline Erosion." Edited by Constantine Goudas, George Katsiaris, Vincent May, and Theophanis Karambas. *Soft Shore Protection: An Environmental Innovation in Coastal Engineering*. Dordrecht: Springer Netherlands, 2003.
- Holmes, Clive. "Drainage Projects in Elizabethan England: The European Dimension'." *Eau et Developpement Dans VEurope Moderne (Paris, 2004)*, 2004, 87–102.
- Hoque, Asiful, Ashif Hasan Abir, and Kironmoy Paul Shourov. "Solar Still for Saline Water Desalination for Low-Income Coastal Areas." *Applied Water Science* 9, no. 4 (2019): 1–8.
- Horstmann, Britta. "Operationalizing the Adaptation Fund: Challenges in Allocating Funds to the Vulnerable." *Climate Policy* 11, no. 4 (2011): 1086–96.
- Hueckel, William Clemens. "Methods of Improving the Mississippi River," 1908.

- Ido, Sella, and Perkol-Finkel Shimrit. "Blue Is the New Green – Ecological Enhancement of Concrete Based Coastal and Marine Infrastructure." *Ecological Engineering* 84 (November 2015): 260–72. h=
- Ishida, Shinichi, Takatsugu Kawano, and Chiaki Sato. Artificial refuge reef for fish. United States US3561402A, filed November 20, 1968, and issued February 9, 1971.
- Iskandarova, Marfuga. "From the Idea of Scale to the Idea of Agency: An Actor-Network Theory Perspective on Policy Development for Renewable Energy." *Science and Public Policy* 44, no. 4 (2017): 476–85.
- Ito, Yasushi. "Artificial Reef Function in Fishing Grounds off Japan." *Artificial Reefs in Fisheries Management*, 2011, 239–64.
- Iuppa, Claudio, Luca Cavallaro, Claudia Giarrusso, Rosaria Ester Musumeci, and Giovanni Savasta. "Coastal Flooding Risk Assessment Through Artificial Intelligence," 2005–9. Springer, 2019.
- JØrgensen, Dolly. "An Oasis in a Watery Desert? Discourses on an Industrial Ecosystem in the Gulf of Mexico Rigs-to-Reefs Program." *History and Technology* 25, no. 4 (2009): 343–64.
- Jaffe, Adam B, and Josh Lerner. *Innovation and Its Discontents: How Our Broken Patent System Is Endangering Innovation and Progress, and What to Do about It*. Princeton University Press, 2011.
- Jee, Su Jung, and Sugandha Srivastav. "Knowledge for a Warmer World: A Patent Analysis of Climate Change Adaptation Technologies." arXiv. org, 2021.
- Jensen, A., K. Collins, and A.P. Lockwood. *Artificial Reefs in European Seas*. Springer Netherlands, 2012.
- Jones, Stacy V. "PATENTS; Synthetic Seaweed' Inhibits Coastal Erosion." *The New York Times*, October 27, 1984,
- Joyce, Justin, Ni-Bin Chang, Rahim Harji, and Thomas Ruppert. "Coupling Infrastructure Resilience and Flood Risk Assessment via Copulas Analyses for a Coastal Green-Grey-Blue Drainage System under Extreme Weather Events." *Environmental Modelling & Software* 100 (2018): 82–103.
- Karinen, Risto, and David H Guston. "Toward Anticipatory Governance: The Experience with Nanotechnology." In *Governing Future Technologies*, 217–32. Springer, 2009.
- Katz, Elihu, Martin L Levin, and Herbert Hamilton. "Traditions of Research on the Diffusion of Innovation." *American Sociological Review*, 1963, 237–52.
- Kauffman, Nate, and Kristina Hill. "Climate change, adaptation planning and institutional integration: A literature review and framework." *Sustainability* 13.19 (2021)
- Kaufman, Wallace., and Orrin H. Pilkey. *The Beaches Are Moving the Drowning of America's Shoreline : With a New Epilogue*. Living with the Shore. Durham, N.C: Duke University Press, 1983..
- Kim, Jinyoung, and Gerald Marschke. "Accounting for the Recent Surge in US Patenting: Changes in R&D Expenditures, Patent Yields, and the High Tech Sector." *Economics of Innovation and New Technology* 13, no. 6 (2004): 543–58.
- Kim, Kyunam, and Yeonbae Kim. "Role of Policy in Innovation and International Trade of Renewable Energy Technology: Empirical Study of Solar PV and Wind Power Technology." *Renewable and Sustainable Energy Reviews* 44 (2015): 717–27.

- Kim, Min, Soojin You, Jinhyung Chon, and Junga Lee. "Sustainable Land-Use Planning to Improve the Coastal Resilience of the Social-Ecological Landscape." *Sustainability* 9, no. 7 (2017): 1086.
- Kitch, Edmund W. "The Nature and Function of the Patent System." *The Journal of Law and Economics* 20, no. 2 (1977): 265–90.
- Kılış, Şiir. "Sustainable Development of Energy, Water and Environment Systems Index for Southeast European Cities." *Journal of Cleaner Production* 130 (2016): 222–34.
- Klein, Richard JT, Robert J Nicholls, Sachooda Ragoonaden, Michele Capobianco, James Aston, and Earle N Buckley. "Technological Options for Adaptation to Climate Change in Coastal Zones." *Journal of Coastal Research*, 2001, 531–43.
- Klerkx, Laurens, and Cees Leeuwis. "Balancing Multiple Interests: Embedding Innovation Intermediation in the Agricultural Knowledge Infrastructure." *Technovation* 28, no. 6 (2008): 364–78.
- Knapp, Whitney. "Impacts of Terminal Groins on North Carolina's Coast," 2012.
- Koerth, Jana, Athanasios T Vafeidis, Silvina Carretero, Horst Sterr, and Jochen Hinkel. "A Typology of Household-Level Adaptation to Coastal Flooding and Its Spatio-Temporal Patterns." *Springerplus* 3, no. 1 (2014): 1–10.
- Koolhaas, Rem. *Content : OMA-AMO, Rem Koolhaas*. Koenig In; London: Taschen, 2004.
- Kousky, Carolyn, Billy Fleming, and Alan M. Berger, eds. *A blueprint for coastal adaptation: Uniting design, economics, and policy*. Island Press, 2021.
- Kurth, Margaret H, Jesse M Keenan, Mehrdad Sasani, and Igor Linkov. "Defining Resilience for the US Building Industry." *Building Research & Information* 47, no. 4 (2019): 480–92.
- Lagemaat, Willem Geert. "Patent Archives—the Silent Threat." *World Patent Information* 27, no. 1 (2005): 27–29.
- Lahoz-Monfort, José J, and Michael JL Magrath. "A Comprehensive Overview of Technologies for Species and Habitat Monitoring and Conservation." *BioScience*, 2021.
- Lamsal, Rabindra, and TV Vijay Kumar. "Artificial Intelligence Based Early Warning System for Coastal Disasters." In *Development in Coastal Zones and Disaster Management*, 305–20. Springer, 2020.
- . "Classifying Emergency Tweets for Disaster Response." *International Journal of Disaster Response and Emergency Management (IJDREM)* 3, no. 1 (2020): 14–29.
- Lane, Eric L. "Building the Global Green Patent Highway: A Proposal for International Harmonization of Green Technology Fast Track Programs." *Berkeley Technology Law Journal*, 2012, 1119–70.
- Lane, Joseph P, and Jennifer L Flagg. "Translating Three States of Knowledge—Discovery, Invention, and Innovation." *Implementation Science* 5, no. 1 (2010): 1–14.
- Latour, Bruno. "On Actor-Network Theory: A Few Clarifications." *Soziale Welt*, 1996, 369–81.
- Laurini, Robert. *Geographic Knowledge Infrastructure: Applications to Territorial Intelligence and Smart Cities*. Elsevier, 2017.
- Lazarus, Eli D. "Toward a Global Classification of Coastal Anthromes." *Land* 6, no. 1 (2017): 13.
- Lee, Moon Ock, Shinya Otake, and Jong Kyu Kim. "Transition of Artificial Reefs (ARs) Research and Its Prospects." *Ocean & Coastal Management* 154 (2018): 55–65.

- Lee, Sungjoo, Byungun Yoon, and Yongtae Park. "An Approach to Discovering New Technology Opportunities: Keyword-Based Patent Map Approach." *Technovation* 29, no. 6–7 (2009): 481–97.
- Lemley, Mark A, and Dan L Burk. "Policy Levers in Patent Law." *Virginia Law Review* 89 (2003): 1575.
- Li, Hongxiu. "Innovation as Adaptation to Natural Disasters," 2017.
- Li, Qinghai, and Ping Deng. "From International New Ventures to MNCs: Crossing the Chasm Effect on Internationalization Paths." *Journal of Business Research* 70 (2017): 92–100.
- Liu, Shurong, Xijie Zhou, Cong Zeng, Tim Frankstone, and Ling Cao. "Characterizing the Development of Sea Ranching in China." *Reviews in Fish Biology and Fisheries*, 2022, 1–21.
- Lloyd, Michael Greg, Deborah Peel, and Robert W Duck. "Towards a Social–Ecological Resilience Framework for Coastal Planning." *Land Use Policy* 30, no. 1 (2013): 925–33.
- Lochhead, Helen. "Resilience by Design: Can Innovative Processes Deliver More?" *Procedia Engineering* 180 (2017): 7–15.
- Loke, Lynette H L, Nicholas R Jachowski, Tjeerd J Bouma, Richard J Ladle, and Peter A Todd. "Complexity for Artificial Substrates (CASU): Software for Creating and Visualising Habitat Complexity." *PloS One* 9, no. 2 (2014): e87990–e87990.
- Lorenzi, Nancy M, Laurie L Novak, Jacob B Weiss, Cynthia S Gadd, and Kim M Unertl. "Crossing the Implementation Chasm: A Proposal for Bold Action." *Journal of the American Medical Informatics Association* 15, no. 3 (2008): 290–96.
- Louime, Clifford, Jodany Fortune, and Gary Gervais. "Sargassum Invasion of Coastal Environments: A Growing Concern." *American Journal of Environmental Sciences* 13, no. 1 (2017): 58–64.
- Lowrey, Walter M. "The Engineers and the Mississippi." *Louisiana History*, 1964, 233–55.
- Lugo, Ariel E. "Effects of Extreme Disturbance Events: From Ecesis to Social–Ecological–Technological Systems." *Ecosystems* 23, no. 8 (2020): 1726–47.
- Maggitti, Patrick G, Ken G Smith, and Riitta Katila. "The Complex Search Process of Invention." *Research Policy* 42, no. 1 (2013): 90–100.
- Mann, Roger. "Restoring Nature's Coastal Architects: A Reality Check." *Ecological Restoration* 31, no. 3 (2013): 323–24.
- Markee, Numa. "The Diffusion of Innovation in Language Teaching." *Annual Review of Applied Linguistics* 13 (1992): 229–43.
- Masys, Anthony J. "'World Views' on Impacts and Responses to Climate Change: An Actor Network Theory Perspective," Vol. 6. IOP Publishing, 2009.
- Mathur, A., D. da Cunha, and University of Pennsylvania. School of Design. *Design in the Terrain of Water*. Applied Research + Design Publishing, 2014.
- McPhee, John. *The Control of Nature*. Thorndike: G.K. Hall, 1999.
- Meade, Nigel, and Towhidul Islam. "Modelling and Forecasting the Diffusion of Innovation – A 25-Year Review." *International Journal of Forecasting*, Twenty five years of forecasting, 22, no. 3 (January 1, 2006): 519–45. <https://doi.org/10.1016/j.ijforecast.2006.01.005>.
- Mendez-Tejeda, Rafael, and Gladys A Rosado Jiménez. "Influence of Climatic Factors on Sargassum Arrivals to the Coasts of the Dominican Republic," 2019.

- Miao, Qing, and David Popp. "Necessity as the Mother of Invention: Innovative Responses to Natural Disasters." *Journal of Environmental Economics and Management* 68, no. 2 (2014): 280–95.
- Miller, J B. *Case Studies in Infrastructure Delivery*. Infrastructure Systems: Delivery and Finance. Springer US, 2012.
- . *Principles of Public and Private Infrastructure Delivery*. Infrastructure Systems: Delivery and Finance. Springer US, 2013.
- Miller, Margaret W. "Using Ecological Processes to Advance Artificial Reef Goals." *ICES Journal of Marine Science* 59, no. suppl (2002): S27–31.
- Mintrom, Michael. "Policy Entrepreneurs and the Diffusion of Innovation." *American Journal of Political Science*, 1997, 738–70.
- Mohammed, Tarek Aa, Hamed Aa, Ezz El-Arab Ma, and El-Moselhy Khm. "Coral Rehabilitation Using Steel Slag as a Substrate." *International Journal of Environmental Protection* 2, no. 5 (2012): 1–5.
- Montecchi, Tiziano, Davide Russo, and Ying Liu. "Searching in Cooperative Patent Classification: Comparison between Keyword and Concept-Based Search." *Advanced Engineering Informatics* 27, no. 3 (2013): 335–45.
- Morton, T. *Hyperobjects: Philosophy and Ecology after the End of the World*. Posthumanities. University of Minnesota Press, 2013.
- Mossop, Elizabeth, ed. *Sustainable coastal design and planning*. CRC Press, 2018.
- Moulaert, Frank, and Abdelillah Hamdouch. "New Views of Innovation Systems: Agents, Rationales, Networks and Spatial Scales in the Knowledge Infrastructure." *Innovation: The European Journal of Social Science Research* 19, no. 1 (2006): 11–24.
- Masoud, Fadi, ed. *Terra-sorta-firma: Reclaiming the Littoral Gradient*. Actar D, Inc., 2021.
- Mowery, David C, Richard R Nelson, Bhaven N Sampat, and Arvids A Ziedonis. *Ivory Tower and Industrial Innovation: University-Industry Technology Transfer before and after the Bayh-Dole Act*. Stanford University Press, 2015.
- Muiderman, Karlijn, Aarti Gupta, Joost Vervoort, and Frank Biermann. "Four Approaches to Anticipatory Climate Governance: Different Conceptions of the Future and Implications for the Present." *Wiley Interdisciplinary Reviews: Climate Change* 11, no. 6 (2020): e673.
- Murdoch, Jonathan. "The Spaces of Actor-Network Theory." *Geoforum* 29, no. 4 (1998): 357–74.
- Mustapa, Muhammad Adli, OB Yaakob, Yasser M Ahmed, Chang-Kyu Rheem, KK Koh, and Faizul Amri Adnan. "Wave Energy Device and Breakwater Integration: A Review." *Renewable and Sustainable Energy Reviews* 77 (2017): 43–58.
- Mvulirwenande, Silas, and Uta Wehn. "Promoting Smart Water Systems in Developing Countries Through Innovation Partnerships: Evidence from VIA Water-Supported Projects in Africa." In *ICT for Smart Water Systems: Measurements and Data Science*, 167–207. Springer, 2019.
- Nard, Craig Allen, and Andrew P Morriss. "Constitutionalizing Patents: From Venice to Philadelphia." *Review of Law and Economics* 2, no. 2 (2006): 223–321.
- NATIONAL ACADEMY OF SCIENCES-NATIONAL RESEARCH COUNCIL WASHINGTON DC, and Hoyt Lemons. "Physical Geography." US Government, 1953.
<https://apps.dtic.mil/sti/pdfs/AD0017348.pdf>.
- National Fishing Enhancement Act of 1984, Public Law 98-623 § (n.d.).

- Nelson, Walter G, and Martin B Main. "Criteria for Beach Nourishment: Biological Guidelines for Sabellariid Worm Reef," 1985.
- Neretin, OP, NV Lopatina, and Yu S Zubov. "Digitization of the Intellectual Property Field: From Scientific Justification to Practical Implementation." *Scientific and Technical Information Processing* 46 (2019): 67–72.
- Nicholson, Simon, Sikina Jinnah, and Alexander Gillespie. "Solar Radiation Management: A Proposal for Immediate Polycentric Governance." *Climate Policy* 18, no. 3 (2018): 322–34.
- Nlenanya, Inya. "Building an Environmental GIS Knowledge Infrastructure." In *Data Mining Applications for Empowering Knowledge Societies*, 260–77. IGI Global, 2009.
- Noyons, ECM, AFJ Van Raan, Hariolf Grupp, and Ulrich Schmoch. "Exploring the Science and Technology Interface: Inventor-Author Relations in Laser Medicine Research." *Research Policy* 23, no. 4 (1994): 443–57.
- Nordenson, Catherine Seavitt, Guy Nordenson, and Julia Chapman. Structures of coastal resilience. Island Press, 2018.
- Nordenson, G., Seavitt, C., Yarinsky, A., & Bergdoll, B. (2010). On the Water: Palisade Bay. New York: Hatje Cantz.
- Ogawa, Y. "Artificial Reef and Fish." *Propagation of Fisheries, Special*, no. 7 (1968).
- Oldham, Paul, Bronislaw Szerszynski, Jack Stilgoe, Calum Brown, Bella Eacott, and Andy Yuille. "Mapping the Landscape of Climate Engineering." *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 372, no. 2031 (2014): 20140065.
- Orff, Kate. "Shellfish as Living Infrastructure." *Ecological Restoration* 31, no. 3 (2013): 317–22.
- Ortego, Tyler R., Robert L. Beine, Steven G. Hall, and Matthew D. Campbell. Artificial material conducive to attract and grow oysters, mollusks or other productive and/or stabilizing organisms. United States US8312843B2, filed June 30, 2006, and issued November 20, 2012.
- Ortego, Tyler Ray. *Analysis of Bioengineered Concrete for Use in a Submerged Reef Type Breakwater*. Louisiana State University and Agricultural & Mechanical College, 2006.
- Owens, David W. "Coastal Management in North Carolina Building a Regional Consensus." *Journal of the American Planning Association* 51, no. 3 (1985): 322–29.
- Oyamada, Kumi, Mario Tsukidate, Keiji Watanabe, Tatsuhito Takahashi, Tsuneo Isoo, and Toshinobu Terawaki. "A Field Test of Porous Carbonated Blocks Used as Artificial Reef in Seaweed Beds of Ecklonia Cava," 413–18. Springer, 2009.
- Park, Seongsik, Jong Ryol Kim, Young Ryun Kim, Seokjin Yoon, and Kyunghoi Kim. "Assessment of Heavy Metals Eluted from Materials Utilized in Artificial Reefs Implemented in South Korea." *Journal of Marine Science and Engineering* 10, no. 11 (2022): 1720.
- Partzsch, Lena. "Smart Regulation for Water Innovation—the Case of Decentralized Rainwater Technology." *Journal of Cleaner Production* 17, no. 11 (2009): 985–91.
- "Patenting Plans." *American Architect and Architecture*. (November 29, 1890): 137–38.
- Paxton, Avery B, Kyle W Shertzer, Nathan M Bacheler, G Todd Kellison, Kenneth L Riley, and J Christopher Taylor. "Meta-Analysis Reveals Artificial Reefs Can Be Effective Tools for Fish Community Enhancement but Are Not One-Size-Fits-All." *Frontiers in Marine Science* 7 (2020): 282.

- Paxton, Avery B, D'amy N Steward, Zachary H Harrison, and J Christopher Taylor. "Fitting Ecological Principles of Artificial Reefs into the Ocean Planning Puzzle." *Ecosphere* 13, no. 2 (2022): e3924.
- Penate, Baltasar, Vicente J Subiela, Fayna Vega, Fernando Castellano, F Julián Domínguez, and Vanessa Millán. "Uninterrupted Eight-Year Operation of the Autonomous Solar Photovoltaic Reverse Osmosis System in Ksar Ghilène (Tunisia)." *Desalination and Water Treatment* 55, no. 11 (2015): 3141–48.
- Perkol-Finkel, Shimrit, Filippo Ferrario, Valentina Nicotera, and Laura Airoidi. "Conservation Challenges in Urban Seascapes: Promoting the Growth of Threatened Species on Coastal Infrastructures." *Journal of Applied Ecology* 49, no. 6 (2012): 1457–66.
- Perkol-Finkel, Shimrit, Tomer Hadary, Andrew Rella, Raviv Shirazi, and Ido Sella. "Seascape Architecture—Incorporating Ecological Considerations in Design of Coastal and Marine Infrastructure." *Ecological Engineering* 120 (2018): 645–54.
- Perkol-Finkel, Shimrit, and Ido Sella. "Ecologically Active Concrete for Coastal and Marine Infrastructure: Innovative Matrices and Designs." In *Proceeding of the 10th ICE Conference: From Sea to Shore—Meeting the Challenges of the Sea*. ICE Publishing, London, 1139–50, 2014.
- Pickering, Helen, David Whitmarsh, and Antony Jensen. "Artificial Reefs as a Tool to Aid Rehabilitation of Coastal Ecosystems: Investigating the Potential." *Marine Pollution Bulletin* 37, no. 8–12 (1999): 505–14.
- Picon, Antoine, and Wendy W Fok. *Digital Property: Open-Source Architecture*. John Wiley & Sons, 2017.
- Pilkey, Orrin H, and J Andrew G Cooper. "'Alternative' Shoreline Erosion Control Devices: A Review." In *Pitfalls of Shoreline Stabilization*, 187–214. Springer, 2012.
- Pilkey, Orrin H, and Howard L Wright III. "Seawalls versus Beaches." *Journal of Coastal Research*, 1988, 41–64.
- Prager, Frank D. "Brunelleschi's Patent." *J. Pat. Off. Soc'y* 28 (1946): 109–109.
- Prasad, N Thulasi, Sucheta Sadhu, KNVV Murthy, Srinivasula Reddy Pilli, S Ramesh, SVS Phani Kumar, G Dharani, MA Atmanand, MB Venkata Rao, and TK Dey. "Carbon-Dioxide Fixation by Artificial Reef Development in Marine Environment Using Carbonated Slag Material from Steel Plant," 1–5. IEEE, 2014.
- Price, W.H. *The English Patents of Monopoly*. Harvard Economic Studies. Harvard University Press
- Quay, Ray. "Anticipatory Governance: A Tool for Climate Change Adaptation." *Journal of the American Planning Association* 76, no. 4 (2010): 496–511.
- Ramm, Lachlan AW, James H Florisson, Stephanie L Watts, Alistair Becker, and James R Tweedley. "Artificial Reefs in the Anthropocene: A Review of Geographical and Historical Trends in Their Design, Purpose, and Monitoring." *Bulletin of Marine Science* 97, no. 4 (2021): 699–728.
- Ramos, J.H.P. *Impact of Artificial Reefs on the Environment and Communities*. Practice, Progress, and Proficiency in Sustainability. IGI Global, 2022.
- Ramos, Jose M. "Anticipatory Governance: Traditions and Trajectories for Strategic Design." *Journal of Futures Studies* 19, no. 1 (2014): 35–52.

- Rankin, William. "The 'Person Skilled in the Art' Is Really Quite Conventional: U.S. Patent Drawings and the Persona of the Inventor, 1870-2005." In *Making and Unmaking Intellectual Property: Creative Production in Legal and Cultural Perspective*, edited by Mario Biagioli and Peter Jaszi. University of Chicago Press, 2015.
- Reuss, Martin. *Designing the Bayous : The Control of Water in the Atchafalaya Basin, 1800-1995*. College Station: Texas A & M University Press, 2004.
- Reuss, Martin. "The Art of Scientific Precision: River Research in the United States Army Corps of Engineers to 1945." *Technology and Culture* 40, no. 2 (1999): 292–323.
- Reymond, David. "Patents Information for Humanities Research: Could There Be Something?" *Iberoamerican Journal of Science Measurement and Communication* 1, no. 1 (2021): 006–006.
- Riggio, Silvano, Fabio Badalamenti, and Giovanni D'Anna. "Artificial Reefs in Sicily: An Overview." *Artificial Reefs in European Seas*, 2000, 65–73.
- Rimmer, Matthew. "Beyond the Paris Agreement: Intellectual Property, Innovation Policy, and Climate Justice." *Laws* 8, no. 1 (2019): 7.
- Rising Currents: Projects for New York's Waterfront*. The Museum of Modern Art, n.d.
- Roch, Cassandra, Sebastian Schmidt-Roach, and Carlos M Duarte. "Coral Restoration Patents Are Disconnected from Academic Research and Restoration Practitioners," 2023.
- ROGERS, Everett Mitchell. *Diffusion of Innovations*. Pp. xiii. 367. Free Press of Glencoe: New York; Macmillan, New York: London, 1962.
- Rogers, Spencer M. "Artificial Seaweed for Shoreline Erosion Control," 1986.
- Rotmans, Jan, René Kemp, and Marjolein Van Asselt. "More Evolution than Revolution: Transition Management in Public Policy." *Foresight*, 2001.
- Roy, Ranjan, Animesh K Gain, Narimah Samat, Margot Hurlbert, Mou Leong Tan, and Ngai Weng Chan. "Resilience of Coastal Agricultural Systems in Bangladesh: Assessment for Agroecosystem Stewardship Strategies." *Ecological Indicators* 106 (2019): 105525.
- Šakić Trogrlić, Robert, Jeroen Rijke, Nanco Dolman, and Chris Zevenbergen. "Rebuild by Design in Hoboken: A Design Competition as a Means for Achieving Flood Resilience of Urban Areas through the Implementation of Green Infrastructure." *Water* 10, no. 5 (2018): 553.
- Saleh, Firas, and Michael P Weinstein. "The Role of Nature-Based Infrastructure (NBI) in Coastal Resiliency Planning: A Literature Review." *Journal of Environmental Management* 183 (2016): 1088–98.
- Sánchez-Corcuera, Ruben, Adrián Nuñez-Marcos, Jesus Sesma-Solance, Aritz Bilbao-Jayo, Rubén Mulero, Unai Zulaika, Gorka Azkune, and Aitor Almeida. "Smart Cities Survey: Technologies, Application Domains and Challenges for the Cities of the Future." *International Journal of Distributed Sensor Networks* 15, no. 6 (2019): 1550147719853984.
- Schellner, Irene. "Japanese File Index Classification and F-Terms." *World Patent Information* 24, no. 3 (2002): 197–201.
- Schmaltz, Emma, Emily C Melvin, Zoie Diana, Ella F Gunady, Daniel Rittschof, Jason A Somarelli, John Viridin, and Meagan M Dunphy-Daly. "Plastic Pollution Solutions: Emerging Technologies to Prevent and Collect Marine Plastic Pollution." *Environment International* 144 (2020): 106067.

- Schmidt-Thomé, Kaisa, and Lasse Peltonen. "Actors, Networks and Actor-Networks in Coping with Sea-Level Rise." *Special Paper-Geological Survey of Finland* 41 (2006): 51.
- Scotchmer, Suzanne. "Patents as an Incentive System." In *Economics in a Changing World*, 281–96. Springer, 1996.
- Scott, James J. "A Passion for the Remarkable." *Constr. Law*. 21 (2001): 46.
- Seaman Jr, William. "Unifying Trends and Opportunities in Global Artificial Reef Research, Including Evaluation." *ICES Journal of Marine Science* 59, no. suppl (2002): S14–16.
- Seaman, W. *Artificial Habitats for Marine and Freshwater Fisheries*. Elsevier Science, 2013.
- Seavitt Nordenson, Catherine, Nordenson, Guy, Chapman, Julia,. *Structures of Coastal Resilience.*, 2018.
- Shakou, Louisa Marie, Jean-Luc Wybo, Genserik Reniers, and Georgios Boustras. "Developing an Innovative Framework for Enhancing the Resilience of Critical Infrastructure to Climate Change." *Safety Science* 118 (2019): 364–78.
- Shallat, Todd. *Structures in the Stream: Water, Science, and the Rise of the US Army Corps of Engineers*. University of Texas Press, 2010.
- Shamsuzzoha, Md, Md Rasheduzzaman, and Rajan Chandra Ghosh. "Building Resilience for Drinking Water Shortages through Reverse Osmosis Technology in Coastal Areas of Bangladesh." *Procedia Engineering* 212 (2018): 559–66.
- Sheaves, Marcus, Ilva Sporne, Catherine M Dichmont, Rodrigo Bustamante, Pat Dale, Roy Deng, Leo XC Dutra, Ingrid van Putten, Marie Savina-Rollan, and Anne Swinbourne. "Principles for Operationalizing Climate Change Adaptation Strategies to Support the Resilience of Estuarine and Coastal Ecosystems: An Australian Perspective." *Marine Policy* 68 (2016): 229–40.
- Sheehy, Daniel J. "Artificial Reef Programs in Japan and Taiwan," 41:184–98, 1981.
- Sherman, Robin L, and Richard E Spieler. "Tires: Unstable Materials for Artificial Reef Construction." *Transactions on Ecology and the Environment* 88 (2006): 215–23.
- Simard, F. "Un Nouveau Plan de Développement Pour Les Pêches Au Japon: Le Marinovation." *Pêche Maritime (La)* 65, no. 1297 (1986): 260–70.
- Simmons, Heather J E. "Categorizing the Useful Arts: Part, Present, and Future Development of Patent Classification in the United States." *Law Libr. J.* 106 (2014): 564–564.
- Sonn, Jung Won, and Michael Storper. "The Increasing Importance of Geographical Proximity in Knowledge Production: An Analysis of US Patent Citations, 1975-1997." *Environment and Planning A* 40 (2008): 1020–39.
- "Space-Borne Sensing and Green Applications - Patent Insight Report," n.d.
- Srinivas, Krishna Ravi. "Role of Open Innovation Models and IPR in Technology Transfer in the Context of Climate Change Mitigation." *DIFFUSION OF RENEWABLE ENERGY TECHNOLOGIES: CASE STUDIES OF ENABLING FRAMEWORKS IN DEVELOPING COUNTRIES- TECHNOLOGY TRANSFER PERSPECTIVE SERIES*, 2011, 147–58.
- Stone, RB, RS Grove, and CJ Sonu. "Artificia] Habitat Technology in the United States. Today and Tomorrow," 11–13, 1991.
- Stone, Richard B, Chester C Buchanan, and Frank W Steimle. *Scrap Tires as Artificial Reefs...* US Environmental Protection Agency, 1974.
- Strumsky, Deborah, and José Lobo. "Identifying the Sources of Technological Novelty in the Process of Invention." *Research Policy* 44, no. 8 (2015): 1445–61.

- Sutton-Grier, Ariana E, Kateryna Wowk, and Holly Bamford. "Future of Our Coasts: The Potential for Natural and Hybrid Infrastructure to Enhance the Resilience of Our Coastal Communities, Economies and Ecosystems." *Environmental Science & Policy* 51 (2015): 137–48.
- Takagi, Yo. "WIPO's New Strategies on Global Intellectual Property Infrastructure." *World Patent Information* 32, no. 3 (2010): 221–28.
- Takahashi, Tatsuhito, and Kazuya Yabuta. "New Application of Iron and Steelmaking Slag." *NKK Technical Report-Japanese Edition-*, 2002, 43–48.
- The New York Times*. "Seawall Built to Cut Raritan Bay Erosion." May 4, 1975, sec. Archives. <https://www.nytimes.com/1975/05/04/archives/seawall-built-to-cut-raritan-bay-erosion.html>.
- Thierry, Jean-Marie. "Artificial Reefs in Japan—a General Outline." *Aquacultural Engineering* 7, no. 5 (1988): 321–48.
- Tur-Sinai, Ofer. "PATENTS AND CLIMATE CHANGE: A SKEPTIC'S VIEW." *Environmental Law* 48, no. 1 (2018): 211–61.
- United States. Army. Corps of Engineers. *Indian River County Beach Erosion Control: Environmental Impact Statement*, 1981.
- United States. Congress. House. Committee on Merchant Marine and Fisheries. Subcommittee on Fisheries and Wildlife Conservation and the Environment. *Artificial Reefs--Fisheries Development: Hearings Before the Subcommittee on Fisheries and Wildlife Conservation and the Environment of the Committee on Merchant Marine and Fisheries, House of Representatives, Ninety-Eighth Congress, First Session, on Artificial Reefs--H.R. 3474, July 18, 1983, Fisheries Development Corporation--H.R. 3806, September 20, November 10, 1983*. U.S. Government Printing Office, 1984.
- United States. Congress. Senate. Committee on Public Works. Subcommittee on Flood Control: Rivers and Harbors. *Omnibus Water Resources Authorizations--1972: Hearings Before the Subcommittee on Flood Control--Rivers and Harbors of the Committee on Public Works, United States Senate, Ninety-Second Congress, Second Session*. Omnibus Water Resources Authorizations--1972: Hearings Before the Subcommittee on Flood Control--Rivers and Harbors of the Committee on Public Works, United States Senate, Ninety-Second Congress, Second Session. U.S. Government Printing Office, 1972.
- United States. Patent and Trademark Office, Support United States. Patent and Trademark Office. Office of Documentation Planning and Control, United States. Patent and Trademark Office. Office of Documentation Planning and Support, United States. Patent Documentation Organizations, and United States. Patent and Trademark Office. Search and Information Resources. *Manual of Classification*. Manual of Classification. U.S. Department of Commerce, Patent and Trademark Office, Search and Information Resources, 1983.
- United States., Patent Office., Bishop, William D., Henry, Joseph,, Hough, Franklin B., Coffin, James H., Smithsonian Institution.,. *Results of Meteorological Observations, Made under the Direction of the United States Patent Office and the Smithsonian Institution from the Year 1854 to 1859, Inclusive, Being a Report of the Commissioner of Patents Made at the First Session of the Thirty-Sixth Congress. Vol. I-II: Pt. 1*. Washington: Govt. Print. Off., 1861.

- U.S. Department of Commerce. 1985. National artificial reef plan. compiled by Richard B. Stone, National Marine Fisheries Service, Washington, D.C. 39 pp, NOAA Technical Memorandum NMFS OF-6 § (n.d.).
- US Government. United States Patent Act (1790).
- Vargo, Stephen L, Melissa Archpru Akaka, and Heiko Wieland. "Rethinking the Process of Diffusion in Innovation: A Service-Ecosystems and Institutional Perspective." *Journal of Business Research* 116 (2020): 526–34.
- Veefkind, Victor, J Hurtado-Albir, Stefano Angelucci, Konstantinos Karachalios, and Nikolaus Thumm. "A New EPO Classification Scheme for Climate Change Mitigation Technologies." *World Patent Information* 34, no. 2 (2012): 106–11.
- Verspagen, Bart. "University Research, Intellectual Property Rights and European Innovation Systems." *Journal of Economic Surveys* 20, no. 4 (2006): 607–32.
- Vicinanza, Diego, Enrico Di Lauro, Pasquale Contestabile, Corrado Gissoni, Javier L Lara, and Inigo J Losada. "Review of Innovative Harbor Breakwaters for Wave-Energy Conversion." *Journal of Waterway, Port, Coastal, and Ocean Engineering* 145, no. 4 (2019): 03119001.
- Walter, David M. Artificial barrier reef. United States US6824327B1, filed May 27, 2003, and issued November 30, 2004.
- Wang, Juite, and Yi-Jing Chen. "A Novelty Detection Patent Mining Approach for Analyzing Technological Opportunities." *Advanced Engineering Informatics* 42 (2019): 100941.
- Watson, J, Gilbert Barnabe, and Regine Barnabe-Quet. *Ecology and Management of Coastal Waters: The Aquatic Environment*. Springer Science & Business Media, 2000.
- Wehn, U, and C Montalvo. "Dynamics of Water Innovation: Foundations of the Field." *Journal of Cleaner Production*, 2017.
- Williamson, L M. *Prominent and Progressive Pennsylvanians of the Nineteenth Century: A Review of Their Careers*. Prominent and Progressive Pennsylvanians of the Nineteenth Century. Record Publishing Company, 1898.
- Williamson, Leland M, Richard A Foley, Henry H Colclazer, Louis N Megargee, Jay Henry Mowbray, and William R Antisdell. *Prominent and Progressive Pennsylvanians of the Nineteenth Century*. Philadelphia: Record Pub. Co., 1898.
- Wilson, A Meriwether W, Robert Mugerauer, and Terrie Klinger. "Rethinking Marine Infrastructure Policy and Practice: Insights from Three Large-Scale Marina Developments in Seattle." *Marine Policy* 53 (2015): 67–82.
- Wisner, George. "American Harbor Engineering." *Scientific American Supplement*, no. 815 (1891).
- Woodruff, Sierra C, Sara Meerow, Missy Stults, and Chandler Wilkins. "Adaptation to Resilience Planning: Alternative Pathways to Prepare for Climate Change." *Journal of Planning Education and Research*, 2018, 0739456X18801057.
- Yang, YunYun, Lucy Akers, Thomas Klose, and Cynthia Barcelon Yang. "Text Mining and Visualization Tools—Impressions of Emerging Capabilities." *World Patent Information* 30, no. 4 (2008): 280–93.
- Yescombe, E. R., , Farquharson, Edward,,. "Public-Private Partnerships : Principles of Policy and Finance," 2018. /z-wcorg/.
<http://search.ebscohost.com/login.aspx?direct=true&scope=site&db=nlebk&db=nlabk&AN=1572333>.

- Yildiz, Bilgehan, Murat Ustaoglu, and Ahmet Incekara. "Investigating Turkey's EV Technology Adoption Level: How Would Turkey Cross the Chasm Through Policies?" *Review of Contemporary Business Research* 3, no. 1 (2014): 11–34.
- Yilmaz, Seda, Colleen Seifert, Shanna R Daly, and Richard Gonzalez. "Design Heuristics in Innovative Products." *Journal of Mechanical Design* 138, no. 7 (2016).
- Youn, Hyejin, Deborah Strumsky, Luis MA Bettencourt, and José Lobo. "Invention as a Combinatorial Process: Evidence from US Patents." *Journal of the Royal Society Interface* 12, no. 106 (2015): 20150272.
- Zhou, Chen. "Can Intellectual Property Rights within Climate Technology Transfer Work for the UNFCCC and the Paris Agreement?" *International Environmental Agreements: Politics, Law and Economics* 19, no. 1 (2019): 107–22.

Websites, podcasts, and web-based resources referenced.

99% Invisible. "Oyster-Tecture." Accessed September 23, 2021.
<https://99percentinvisible.org/episode/oyster-ecture/>.

American Society of Landscape Architect "2022_ASLA_STEM_White_Paper.Pdf." Accessed May 11, 2023. https://www.asla.org/uploadedFiles/2022_ASLA_STEM_White_Paper.pdf.

"August Muench Oral History Interview." Accessed September 17, 2021.
<https://digital.lib.usf.edu/SFS0050335/00001>.

"A Massive Seaweed Bloom in the Atlantic." NASA Earth Observatory, April 7, 2023.
<https://earthobservatory.nasa.gov/images/151188/a-massive-seaweed-bloom-in-the-atlantic>.

"Changing Course." Accessed April 9, 2022. <http://changingcourse.us/>.

"Code for America." Accessed March 10, 2023. <https://codeforamerica.org/>.

"Code for Change." Accessed March 10, 2023. <https://codeforchangenepal.com/>.

"CPC Definition - E02B HYDRAULIC ENGINEERING (Ship-Lifting E02C; Dredging E02F)." Accessed February 8, 2021. <https://www.uspto.gov/web/patents/classification/cpc/html/defE02B.html>.

"CPC Scheme - A01K ANIMAL HUSBANDRY; CARE OF BIRDS, FISHES, INSECTS; FISHING; REARING OR BREEDING ANIMALS, NOT OTHERWISE PROVIDED FOR; NEW BREEDS OF ANIMALS." Accessed February 26, 2023. <https://www.uspto.gov/web/patents/classification/cpc/html/cpc-A01K.html#A01K>.

"CPC Scheme - Y02A TECHNOLOGIES FOR ADAPTATION TO CLIMATE CHANGE." Accessed May 9, 2023. <https://www.uspto.gov/web/patents/classification/cpc/html/cpc-Y02A.html>.

“A Closer Look at The Natrx OysterBreak System.” *Natrx Adaptive Infrastructure* (blog), March 1, 2021. <https://natrx.io/the-natrx-oysterbreak-system>.

“Engineering With Nature.” Accessed November 15, 2022. <https://ewn.erdcdren.mil/>.

“Espacenet – Patent Classification.” Accessed February 8, 2021. <https://worldwide.espacenet.com/patent/cpc-browser#!/CPC=Y02A>.

“Espacenet – Search Results.” Accessed May 24, 2023. <https://worldwide.espacenet.com/patent/search/family/059381661/publication/NL2018882B1?q=pn%3DNL2018882B1>.

“Espacenet – Search Results.” Accessed May 17, 2023. <https://worldwide.espacenet.com/patent/search?q=cpc%20%3D%20%22Y02A%22%20AND%20pd%20%3E%20%2201%2F01%2F2018%22>.

“Milestones: Pearl Street Station, 1882,” ETHW. June 14, 2022. https://ethw.org/Milestones:Pearl_Street_Station,_1882.

European Patent Office. “CPC NOTICE OF CHANGES 457,” February 1, 2018. <https://www.uspto.gov/web/patents/classification/cpc/pdf/CPCNOC457DP0187A01K.pdf>.

FlaglerLive. “Flagler County’s Holmberg Problem: Beach Erosion Guru Dredges Up Skepticism.” *FlaglerLive* (blog), July 31, 2012. <https://flaglerlive.com/42032/dick-holmberg-technologies/>.

GOV.UK. “A Worldwide Overview of Flood and Coastal Defence Patents.” Accessed July 10, 2023. <https://www.gov.uk/government/publications/a-worldwide-overview-of-flood-and-coastal-defence-patents>.

“The Unbearable Burden of the Technosphere.” UNESCO, March 27, 2018. <https://en.unesco.org/courier/2018-2/unbearable-burden-technosphere>.

“Underwater Tire Reef Experiment In Guam To Be Cleaned Up.” Hawai’i Public Radio, January 19, 2020. <https://www.hawaiipublicradio.org/local-news/2020-01-19/underwater-tire-reef-experiment-in-guam-to-be-cleaned-up>.

“Hurricane Sandy Design Competition – Rebuild by Design.” Accessed June 2, 2023. <https://rebuildbydesign.org/hurricane-sandy-design-competition/>.

“Japanese Artificial Reefs.” Accessed March 1, 2023. <http://www.aquabio.com/japanese-artificial-reefs.html>.

“Land Art Generator.” Accessed June 2, 2023. <https://landartgenerator.org/index.html>.

Low Carbon Patent Pledge. “The Pledge,” August 26, 2021.
<https://lowcarbonpatentpledge.org/the-pledge/>.

Microplastic Removal Systems. “About the System.” Accessed November 24, 2021.
<https://microplasticremovalsystems.com/about-the-system/>.

“Missouri2015.Pdf.” Accessed June 6, 2019.
https://www.asla.org/uploadedFiles/CMS/Government_Affairs/State_Government_Affairs_and_Licenses/State_Documents/Missouri2015.pdf.

“Ocean Decade – The Science We Need For The Ocean We Want.” Accessed July 10, 2023.
<https://oceandecade.org/>.

European Patent Office. “Firefighting Technologies.” Accessed July 10, 2023.
<https://www.epo.org/news-events/in-focus/firefighting.html>.

European Patent Office “IP5 Offices Discuss Office-Led Initiatives on Climate-Related Innovations.” Accessed July 10, 2023. <https://www.epo.org/news-events/news/2023/20230621.html>.

“OpenAI.” Accessed March 10, 2023. <https://openai.com/>.

“Kate Orff: Reviving New York’s Rivers -- with Oysters! | TED Talk.” Accessed June 2, 2023.
https://www.ted.com/talks/kate_orff_reviving_new_york_s_rivers_with_oysters.

“OysterBreak, a New Coastal Restoration System, to Appear in Entrepreneur Week’s Water Challenge | Business News | Nola.Com.” Accessed November 4, 2022.
https://www.nola.com/news/business/article_da9e3221-0d12-5c2c-80a2-f594f1c50aa7.html.

“Oyster-Tecture and the Gowanus Canal | ArchDaily.” Accessed June 2, 2023.
<https://www.archdaily.com/165568/oyster-ecture-and-the-gowanus-canal>.

“Patenting-Climate-Change-Mitigation-Technologies-En.Pdf.” Accessed June 27, 2023.
<https://ised-isde.canada.ca/site/canadian-intellectual-property-office/sites/default/files/attachments/2022/patenting-climate-change-mitigation-technologies-en.pdf>.

“Reinforced Mangrove Protective Infrastructure.” Accessed May 23, 2023.
<https://www.holcimfoundation.org/projects/reinforced-mangrove-protective-infrastructure-miami-fl-usa>.

“Resilience-Point-of-View-Technology.Pdf.” Accessed June 29, 2023.
https://resilientcitiesnetwork.org/downloadable_resources/UR/Resilience-Point-of-View-Technology.pdf.

Restore the Mississippi River Delta. “Changing Course.” Accessed June 19, 2023.
<https://mississippiriverdelta.org/changing-course/>.

“SAIC | Sensor Buoys Help the World Track Tsunamis.” Accessed May 7, 2023.
<https://www.saic.com/features/Sensor-Buoys-Help-The-World-Track-Tsunamis>.

Saving Beaches and Dunes - Holmberg, 2010.
<https://www.youtube.com/watch?v=wA7D8UERl6A>.

Stormtrap. “Stormwater Litter, Trash & Debris Removal | CSO Trash Control.” Accessed June 21, 2023. <https://stormtrap.com/products/trashtrap/>.

Suncorp. “Resilience Rd.” Accessed April 26, 2022. <https://resilience.suncorp.com.au/resilience-rd/>.

“SUNPave – Tomorrow’s Energy Today.” Accessed June 21, 2023. <https://sun-pave.com/>.

Suncorp. “Resilience Rd.” Accessed April 26, 2022. <https://resilience.suncorp.com.au/resilience-rd/>.

“SUNPave – Tomorrow’s Energy Today.” Accessed June 21, 2023. <https://sun-pave.com/>.

“The Ocean’s Biggest Garbage Pile Is Full of Floating Life - The New York Times.” Accessed May 6, 2023. <https://www.nytimes.com/2022/05/06/science/great-pacific-garbage-patch-pollution.html>.

“The Ten Point Plan for a Green Industrial Revolution.” HM Government, n.d.
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/936567/10_POINT_PLAN_BOOKLET.pdf.

“This 72-Year-Old Used A Washing Machine Motor To Build ‘Wave Robber.’” Accessed June 7, 2023. <https://www.fastcompany.com/3013539/this-72-year-old-used-a-washing-machine-motor-to-build-wave-robber-save-the-s>.

“TPWD Artificial Reefs Interactive Mapping.” Accessed February 28, 2023.
<https://tpwd.texas.gov/gis/ris/artificialreefs/>.

“True Flood Risk - Global AI-Driven Risk Management Platform.” Accessed May 24, 2023.
<https://truefloodrisk.com/#/>.

“U.S. Army Corps of Engineers Headquarters > About > History > Brief History of the Corps > Improving Transportation.” Accessed May 23, 2023.
<https://www.usace.army.mil/About/History/Brief-History-of-the-Corps/Improving-Transportation/>.

“US-INERO-Flood-Barriers.Pdf.” Accessed May 24, 2023.
<https://floodcontrolinternational.com/wp-content/uploads/2020/11/US-INERO-Flood-Barriers.pdf>.

Web Leads. “Gulf Coast AquaDams in Abbeville, LA.” Accessed June 21, 2023.
<https://GULFCOASTAQUADAMS.COM/>.

Welcome to NOAA Research. “NOAA, U.S. Patent and Trademark Office Create Work-Sharing Program to Advance Green Technology.” Accessed May 2, 2023.
<https://research.noaa.gov/article/ArtMID/587/ArticleID/2944/NOAA-US-Patent-and-Trademark-Office-create-work-sharing-program-to-advance-green-technology>.

“William J. Mouton, 70, Engineer and Professor - The New York Times.” Accessed June 7, 2023.
<https://www.nytimes.com/2001/07/08/us/william-j-mouton-70-engineer-and-professor.html>.

Wired. “Alphabet’s Sidewalk Labs Scraps Its Ambitious Toronto Project.” Accessed November 13, 2020. <https://www.wired.com/story/alphabets-sidewalk-labs-scraps-ambitious-toronto-project/>.

“World Intellectual Property Organization.” Text. Accessed June 14, 2023.
<https://www.uspto.gov/ip-policy/patent-policy/world-intellectual-property-organization>.

MARK SCHLEIFSTEIN.. “Dr. Sherwood ‘Woody’ Gagliano, ‘Paul Revere’ of Coastal Land Loss, Dead at 84.” NOLA.com. Accessed September 17, 2021.
https://www.nola.com/news/environment/article_8574789a-c965-11ea-8e4d-eb4baf9881e.html.