Liquid Dreams

Envisioning Water Futures in the UAE

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This publication was produced for the 2019 Art Jameel Arts Writing and Research Commission and is the outcome of a three-month residency at the Jameel Arts Centre in Dubai.
Nadia Christidi was selected through a juried open call process. The jury included writer, translator and curator Omar Berrada, editor and writer Negar Azimi and writer and curator Nida Ghouse.

Author's Acknowledgements
Special thanks to the Jameel Arts Centre team who made my residency an unforgettable experience, and reviewed and gave feedback on earlier versions of this text, especially Lana Shamma, Uns Kattan, Nadine Ghandour, and Antonia Carver. Thanks as well to the staff at the Juma Al-Majid Centre for Culture and Heritage and the *Gulf News* archive for their assistance in my research and for all those who agreed to be interviewed during my time in Dubai. My heartfelt appreciation to friends and family who read, listened, and thought through things with me at different points – Theodore Christidis, Omar Christidis, Rayya Badran, Sary Moussa, Nadim Choufi, Raafat Majzoub, Murtaza Vali, and Faysal Tabbarah, Rijul Kochhar, and Michael M. J. Fischer.

ART JAMEEL

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In 2015, landscape architect Richard Hindle asked what America's riverine landscapes, including the Mississippi River Basin and Sacramento-San Joaquin Delta, might have looked like had technologies that were proposed to manage rivers besides established forms of levees seen the light. Beginning with the problematic that levees, as they have been ubiquitously built since the 20th century, have both enabled flood control and navigability but also generated much ecological harm, Hindle mines patent archives for levee designs that proposed to manage flows differently and muses on the landscapes that could have resulted had they been deployed. For Hindle, such an approach might allow us to "critique or reimagine an infrastructure that is so deeply embedded in society" that it is difficult to imagine otherwise.[1]

Hindle does here what, one might argue, many historicizations do: render the present not as inevitable, natural, or the only way possible, but as the product of contingencies and circumstance. During the time I spent researching the future of water in Dubai, visions articulated to me by water stakeholders imagined the future - in no uncertain terms - as entailing, well, more desalination. There was overwhelming agreement that desalination just makes sense. The UAE's desalination plants seemed to stand right alongside Hindle's deeply embedded levees. But a small foray into the archive to understand how this inevitability was constructed shows that even as late as the 1990s, questions around desalination's long term viability were not unheard of;[2] rather, discursive, material, financial, and political investments (and interests) over the years have led to desalination's entrenchment, generating a path dependency that is challenging to question and counter.[3] Today, certainty is projected backwards onto the past such that desalination comes to have made sense *all along*. But there were once and there continue to be visions of the future of water beyond just desalination.

As I dove into historical material, I stumbled on proposals for alternatives or supplements to desalination that appeared only to

disappear then reappear. In the early 1980s, for instance, Mitsui & Co. proposed to use oil tankers returning empty from Japan to ship water from Yakushima island to the UAE.[4] The proposal acknowledged precedent in *abwam miyah* - boats that transported water from Shatt Al Arab to Kuwait in its pre-oil and desalination days.[5] But tankering water, which Mistui & Co. never did, made a comeback by 1996, when a scheme to transport water by tankers from Kenyir Lake in Malaysia to the Arabian Gulf was reported on that even saw Danish shipping giant Maersk promise a tanker supply.[6] Transnational water pipelines were proposed to connect the UAE to water sources in Turkey, Lebanon, and Pakistan in the 1980s and 1990s, with pipelines changing points of origin and trajectories - as well as palatability - with changes in political winds.[7] Towing icebergs to be harvested for freshwater, which had a champion in Saudi prince Mohammed bin Faisal in the 1970s,[8] found a new advocate in Emirati entrepreneur Abdullah El Shehi, who has been planning to tow icebergs to Fujairah since the 2010s.[9] And historic agricultural revolutions aiming at Gulf food self-sufficiency - precipitated by a Western threat of a grain embargo[10] following the Arab oil embargo - bear resonances with ongoing ag-tech revolutions working to make water footprints near-disappear.

Writing of echoes across time, and specifically across past and present visions of Emirati technology-enabled agricultural revolutions, geographer Natalie Koch shows how contemporary ag-tech imaginaries, which are thought to be novel, actually reproduce the promises made by earlier initiatives now largely forgotten. Koch calls this phenomenon "spectacular forgetting," where spectacular visions of the future are strategically mobilized, forgotten, and repeated and where the fact of their repetition - and previous 'failure' - is unrecalled.[11] Significantly for Koch, spectacular visions of future transformations (ie. modernization, development, innovation) are 'political technologies' - things that have political effects[12] that are tied to how and by whom they are wielded. As she writes: "actors with access to different social, financial, institutional, and scientific resources are the buyers and sellers of spectacle, and how they traffic in it makes this a political story."[13] Following Koch, we need to attend to the politics of forgetting and repetition amidst novelty claims about water futures, and to what visions are being trafficked in and in what ways.

Over the last two decades, for instance, unconventional water resources,[14] which include desalination and wastewater recycling[15] but also iceberg towing, fog harvesting, cloud seeding, tankering, and micro-catchment stormwater capture,[16] have come to be increasingly seen globally as "a new resource frontier."[17] Unconventional water resources are previously untapped or minimally tapped resources that require unconventional processes, often involving new and complex technological interventions, for their exploitation. These are imagined as solutions for bridging the 'water gap' between growing demand and dwindling supplies, which is expected to lead to future water crises.[18] But different unconventional water

resources, as historic proposals for securing water show, have been around and have remained unrealized for some time. Such proposals have generally proliferated or been revived during periods of perceived resource scarcity (like the 1970s and late 2000s)[19] and have abated during moments when resources were understood to be abundant (like most of the 1980s and 1990s, when technological innovation, competitive markets, and trade policies seemed to promise widely available goods at low costs).[20]

The following four essays revolve around four proposals for the future of water in the UAE that emerged in various time periods - and that have in some cases lingered: from a crop revolution imagined in the 1970s and cloud seeding operations conducted as early as 1982 to an iceberg towing scheme in the 2010s and genetically engineered bio-desalination plants envisioned for 2050. Each story focuses on a particular object of water - crops, clouds, icebergs, and genes - to historicize a particular proposal and excavate its predecessors and roots; explore how or why its promises remain largely unfulfilled; and question what this might mean for its viability as a present-day proposed solution. It ends by speculating on what could have been or what could still be were it to fully materialize, particularly as such solutions become increasingly attractive with heightened global water security fears. Along the way, the values embedded in proposals are unpacked for what they can tell us about 'our' relations to nature and technology, among other things, from our fantasies of transcending nature and its limits (see crops and icebergs) and developing the capacity to harness nature's unending abundance to put it to work (see genes) to collaborating with nature to make it more 'efficient' (see clouds).

Returning to Hindle, the significance of what I undertake is not just about recovering forgotten pasts, for, as he notes, "if every lost invention represents an alternate history, it also contains the seeds of a possible future."[21] My hope here is to open up our thinking around what is possible in the future of water, not to advocate for any of these particular alternatives, which, as I show, are potentially problematic in different ways, but to underscore that other futures - other worlds - are indeed available. But I also hope that through this problematization, it becomes ever more clear that there is no such thing as a golden techno-fix, that all techno-fixes have societal implications, and that achieving another world requires radical techno-societal transformation.

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11 Natalie Koch, “AgTech in Arabia: ‘Spectacular Forgetting’ and the Technopolitics of Greening the Desert,” *Journal of Political Ecology 26*, no. 1 (2019): 666-686.
12 Ibid., 671.
13 Ibid., 669.
14 Joe Williams, Ross Beveridge, and Pierre-Louis Mayaux, “Unconventional Waters,” 429.
15 While these forms of water production are well established in the UAE and Arabian Gulf more generally, they are less so in other parts of the world.
16 Manzoor Qadir, Vladimir Smakhtin, Sasha Koo-Oshima, and Edeltraud Guenther, eds., *Unconventional Water Resources* (Cham: Springer Nature Switzerland AG, 2022).
17 Joe Williams, Ross Beveridge, and Pierre-Louis Mayaux, “Unconventional Waters,” 429.
18 Ibid., 430-431.
19 Gavin Bridge, “Material Worlds: Natural Resources, Resource Geography and the Material Economy,” *Geography Compass* 3, no. 3 (May 2009): 1217-1218.
20 Ibid., 1218.
21 Richard Hindle, “Levees that Might Have Been.”

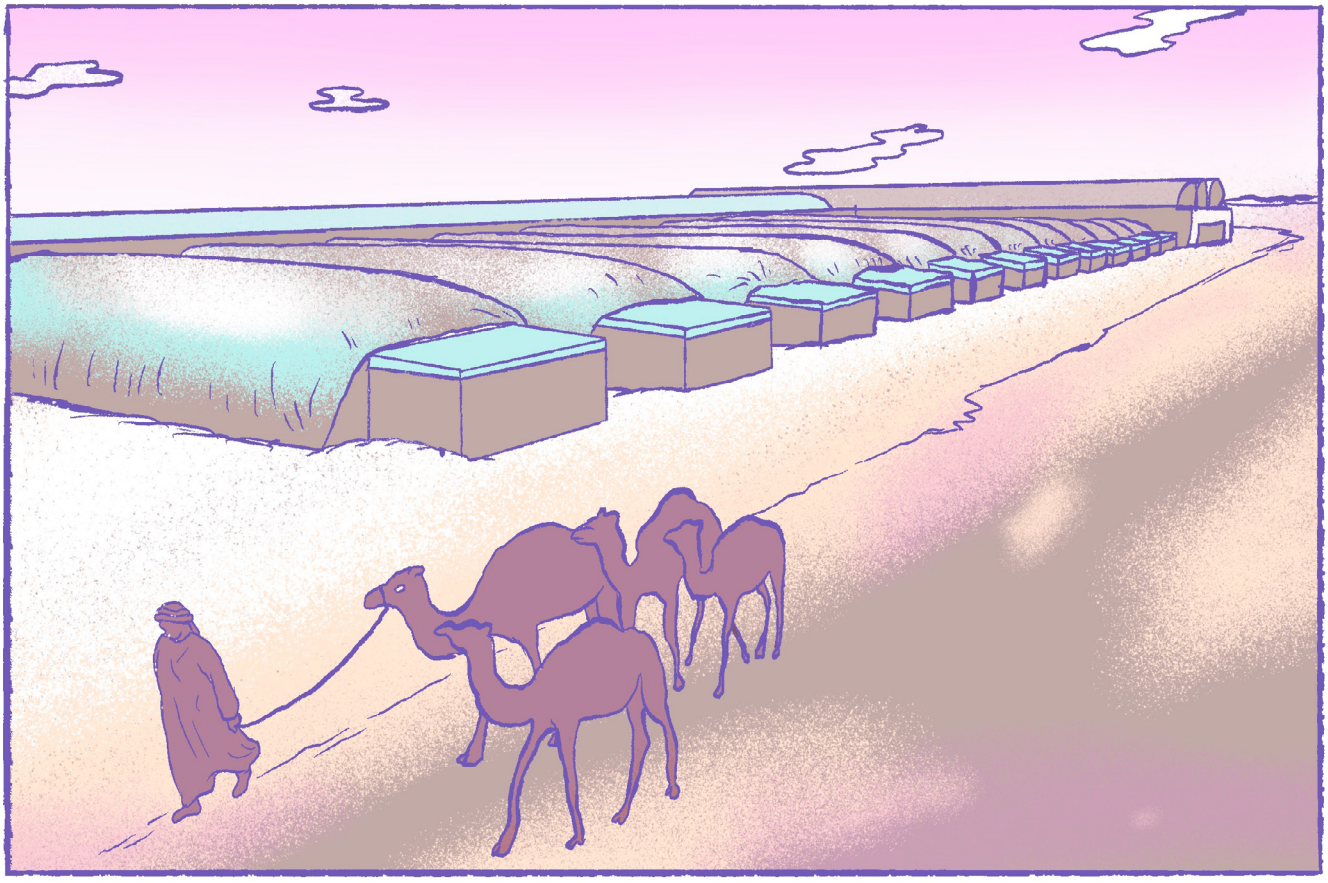
Crops

By the late 1970s, half of sand-swept Saadiyat Island in the Emirate of Abu Dhabi was covered with a complex of air inflated and fiberglass greenhouses. Inside these controlled environments, rows of tomato, cucumber, lettuce, and cabbage plants sprouted from the terrain. Water was evaporated to cool the circulating air and desalinated onsite to irrigate crops through overhead spray, surface drip, and hydroponic systems. Technology was turning the desert into a new type of productive farmland; fantasies of transcending nature's limits through human ingenuity, it seemed, had finally come true. The Saadiyat greenhouses belonged to the Abu Dhabi Arid Lands Research Centre, where experiments in irrigation and in hydroponics were run from around 1970. The center was established with assistance from the University of Arizona, which had undertaken similar work in the Sonoran Desert in Mexico. In 1973, five acres of greenhouses, it was reported, were yielding an average of one ton of produce daily. Vegetables rooted in plastic tubes filled with water were being grown to harvest in just 24 days.[1] The Saadiyat initiative was one of many launched as part of the Emirati government's "green revolution" under its first president Shaikh Zayed bin Sultan Al Nahyan.[2]

In the 1970s and 1980s, agriculture fever swept across the Arabian Gulf, including the UAE, as self-sufficiency in food production came to be prioritized. The West's position on the 1973 Arab-Israeli War had led Arab nations to mount the 1973 Arab Oil Embargo and triggered threats of a US-led grain export boycott in response. Soaring oil prices during the 1979 Second Oil Crisis had resulted in calls for a grain producers' cartel to systematically counter the influence of the Organization of the Petroleum Exporting Countries (OPEC). Arabian Gulf countries became increasingly concerned about their dependence on food imports, which left them vulnerable to the food trade's politicization; these concerns recalled memories of World War II-era experiences of food import disruptions in the Gulf. To reduce import dependence, extensive domestic agriculture programs were developed and foreign agro-investments were made in nearby 'friendly countries.' Oil revenues

enabled the creation and subsidization of such initiatives.[3] Saudi Arabia, for example, heavily invested oil revenues in a subsidized wheat farming program beginning in the 1970s that turned the country into the sixth largest wheat exporter in the world by the early 1990s – and drained its groundwater resources.[4]

As a major target of Arabian Gulf agro-investments in the 1970s, Sudan was a primary site of 'Arab self-sufficiency dreams.' Gulf governmental institutions planned and supported projects aimed at turning Sudan into the 'breadbasket of the Arab World.'[5] The heavily Gulf-funded, Kuwait-based multilateral Arab Fund for Economic and Social Development (AFESD), for example, had a decade-long "Basic Programme for Agricultural Development 1976-1985" that sought to develop Sudan's agricultural capacity to make Arab countries more food secure. The expansion of cultivated lands, agro-processing facilities, and infrastructures such as roads and ports was to enable Sudan to produce and export 42% of Arab countries' edible oils imports, 20% of their sugar imports, and 15% of their wheat imports.[6] Gulf agro-investments were quickly scaled down, however, and projects - if built - hardly went beyond pilot phases. Low yields and high costs made these initiatives economically unviable. Infighting among Arab countries, shifting geopolitics, and the waning Western threat to Arab food security were among the many hurdles the program's execution faced.[7]



Despite its very limited cultivable lands and water resources, which were nowhere near those of Saudi Arabia, the UAE had sizable agricultural ambitions.[8] Shaikh Zayed, as I'm told, was adamant to establish an agricultural sector.[9] In 1979, the UAE Ministry of Agriculture and Fisheries was operating with a bold "target of five years to achieve self sufficiency in food."[10] By 1980, *Al Ittihad* newspaper was boasting that 32% of domestic needs were being satisfied by local agriculture, livestock, and fisheries, and predicting an increase to 60% within a decade. Even if self-sufficiency might never be *fully* achieved, it conceded, sufficiency in some produce at certain times of the year was in fact within reach. Emirati-grown tomatoes and watermelons, it announced, were already being exported to Lebanon and Qatar respectively![11] Apart from bolstering food security and producing crops for export, agricultural initiatives were promoted as a way to enhance the environment, improve local standards of living, diversify economic development[12] beyond the lucrative jobs opened up by a booming oil industry, and keep people connected to the land.[13]

Post-independence initiatives built on modest mid-century agricultural modernization efforts begun by the British in collaboration with Emirati shaikhs. Chief among British efforts was the Agricultural Trials Station founded in Digdaga in Ras Al Khaimah in 1955, where research and demonstrations aimed to encourage the transition from traditional, subsistence farming to technoscientific, market-oriented agriculture.[14] Agricultural land and water development helped establish the hold of coastal Emirati shaikhs over the interior under British rule, and became part of the social contract after independence: Emirati citizens were given incentives by the state to attract them to farming including free land, free water, and interest-free credit and the Emirati state in return gained support and control over territory. From the early 1960s, agricultural initiatives were also imagined - by the British and by Emirati leaders - as a way to establish stability in the face of socio-cultural disruptions introduced by oil wealth.[15]

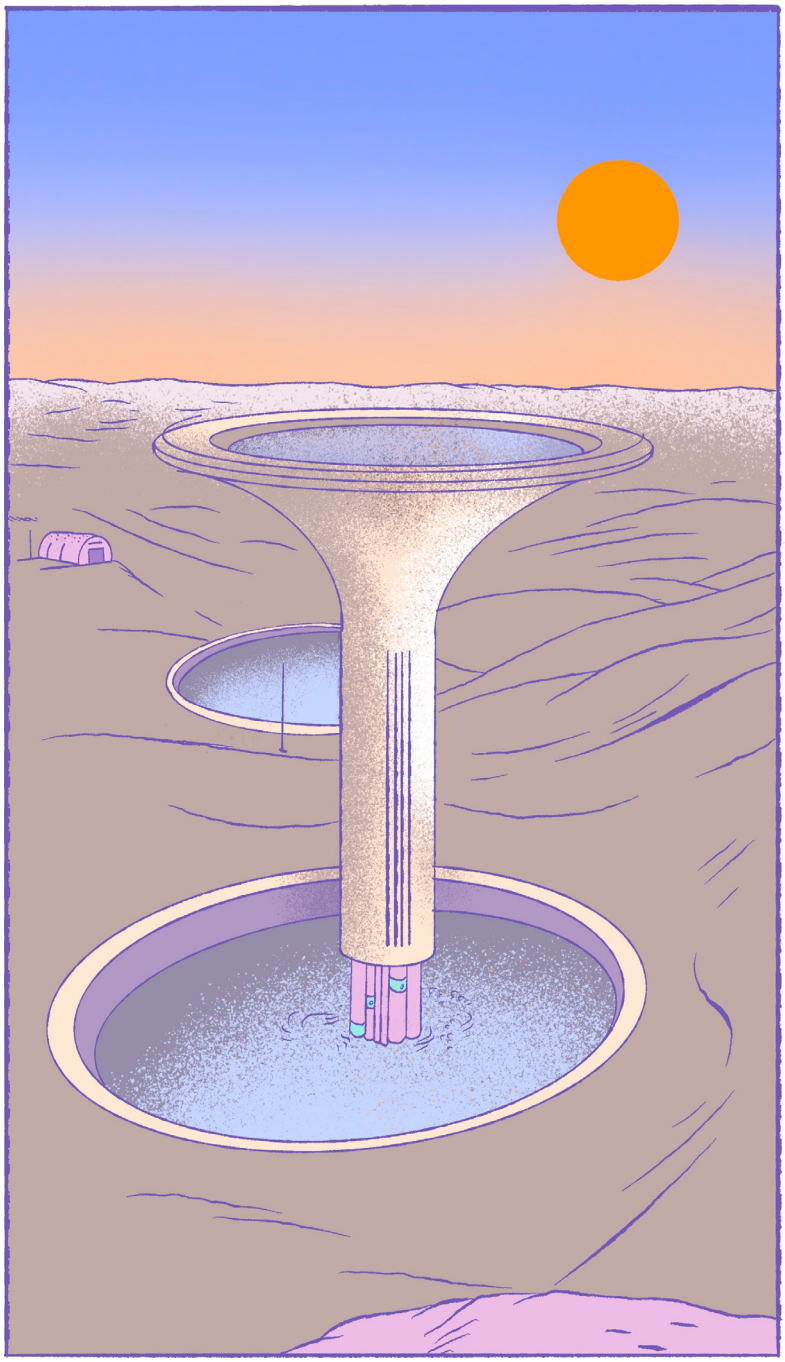
Investments in agricultural development went hand in hand with investments in research and technology. By 1979, centers dedicated to arid lands agricultural research had been established, for instance, in Saadiyat, Al Salamat and Mezyad, and eight agricultural trials stations and nurseries dotted the UAE.[16] The Al Ain Agricultural Centre - launched in 1967 - experimented with cross breeding seed varieties to produce aridity and salinity tolerant crops to grow in winter harvests in its 1200 acre-complex.[17] In Al Salamat, underground asphalt films were tested to halt salinization from irrigation.[18] In Mezyad, a commercial controlled-environment agriculture project was piloted following the success of Saadiyat's greenhouses.[19] And at the British-founded trials station in Digdaga - a "model complex" with an agricultural school - produce ranging from "luxury strawberries" to "basic radishes" was cultivated.[20]

Agricultural production relied on groundwater, the extraction of which far outstripped replenishment.[21] "Water scarcity has rendered self-sufficiency but a dream," concludes one food security scholar on Arabian Gulf agricultural aspirations.[22] Even in the early 1980s, water was recognized as *the* biggest challenge to achieving food self-sufficiency in the UAE.[23] In response, the government made extensive investments in water infrastructures - wells were dug, dams were developed to capture rainwater in the wadis, and 'modern' and drip irrigation systems were expanded on state and private farms.[24] A slew of studies exploring UAE groundwater reserves in the hopes of finding and tapping new sources were also commissioned; these included a multi-year master water and soil study conducted by French company Sogreah starting in 1978.[25] Indiscriminate, uncoordinated well construction and inefficient water use, it was bemoaned, were already drying up wells or making them salty across the country, with Ras Al Khaimah wells making fairly regular appearances in the news.[26] A central water authority was set up to manage water resources and consumption,[27] dam construction was escalated,[28] and tests were carried out on sprinkler, bubble, and drip irrigation.[29]

Despite initial self-sufficiency hopes, by the early 1990s, a much more populated UAE still imported 70% of its food, and agriculture accounted for only 2% of the country's GDP.[30] These days, food imports lie at over 90%. Such numbers are a reflection in part of population growth and resource limits,[31] and in part of changing ideas about food security globally, where food security's meaning has been extended beyond self-sufficiency since the 1980s. In the UAE, local production remained an important food security tenant and areas under cultivation were expanded, even if aspirations for self-sufficiency were scaled back. Most of the emirates including Abu Dhabi have continued to emphasize more efficient local production in their approaches to food security. Dubai - the economy of which revolves around trade and which has invested heavily in trade infrastructure - has been the outlier, with trade being very much front-and-center in its food security plans.[32]

Concerns over reliance on food imports in the UAE resurfaced prominently during the 2008 food crisis, which saw countries impose food export restrictions;[33] these concerns were made ever more urgent by the supply chain disruptions caused by the Covid-19 pandemic.[34] Since the late 2000s, food security has gained renewed UAE policy visibility. Calls have resounded to diversify food trade sources. Interest has intensified in developing local production by supporting ag-tech startups involved in "efficient, sustainable, technology-enabled" farming. And international agro-investments have once again been prioritized.[35] Institutionally, the Abu Dhabi government established the Food Security Center - Abu Dhabi in 2010; the center's efforts to address food security across the country (and not just in Abu Dhabi) were cemented at the federal level with the founding of the Ministry of Food Security in 2017. In the meantime, the private sector was also involved with the creation,

in 2015, of the Food Security Alliance - a coalition of private companies and government bodies working to achieve food security goals on issues ranging from developing in-country and foreign investments to establishing new trade channels. The Minister of Food Security was tasked with creating a unified national food security plan, accelerating the adoption of ag-tech suitable for the UAE's arid and water-scarce conditions, and building a food research and development agenda to ensure more sustainable future food systems.[36] Among the ministry's stated goals in 2018 was increasing local food production by 40%.[37]



Visions of advanced ag-tech have reignited aspirations for intensified local production – and for transcending previously untranscendable limitations.[38] Picture this: Climate-controlled greenhouses and warehouses packed with stacks of hydroponic, aquaponic, and aeroponic-grown plants exposed to custom-tailored hours of LED light, irrigated by solar-powered desalination, and collected by harvest bots in 100,000 agricultural seasons a year.[39] Such visions are materializing through ag-tech initiatives germinating across the country.

In Abu Dhabi, rising ag-tech startup Pure Harvest Smart Farms, which was established in 2016, "wants to disrupt the imported fresh produce industry by making high-quality, sustainably-grown fresh produce year-round."[40] It grows hydroponic leafy greens, tomatoes, and strawberries in controlled-environment greenhouses with water sourced from atmospheric humidity; sensors provide a stream of data that gives insights into plant performance including temperature and hydration conditions.[41] The Abu Dhabi Investment Office launched

a 1 billion AED initiative to support ag-tech companies in 2019 as part of Abu Dhabi's bid to establish itself as a tech-enabled desert agriculture leader;[42] the program sought to invest, in particular, in "precision farming and agricultural robotics, indoor farming, and bioenergy (algae)."[43] Among the companies it supported is Pure Harvest Smart Farms.[44] In Dubai, Badia Farms - the Arabian Gulf's first commercial vertical agriculture project - was launched in 2016, and moved production from the greenhouse into the soilless and sunless urban warehouse.[45] Emirates Crop One, the world's largest vertical farm, also opened in Dubai in 2022; here, leafy greens are cultivated in hydroponic systems that draw on machine learning, AI, and data analytics and that are overseen by engineers and computer scientists in addition to botanists.[46]

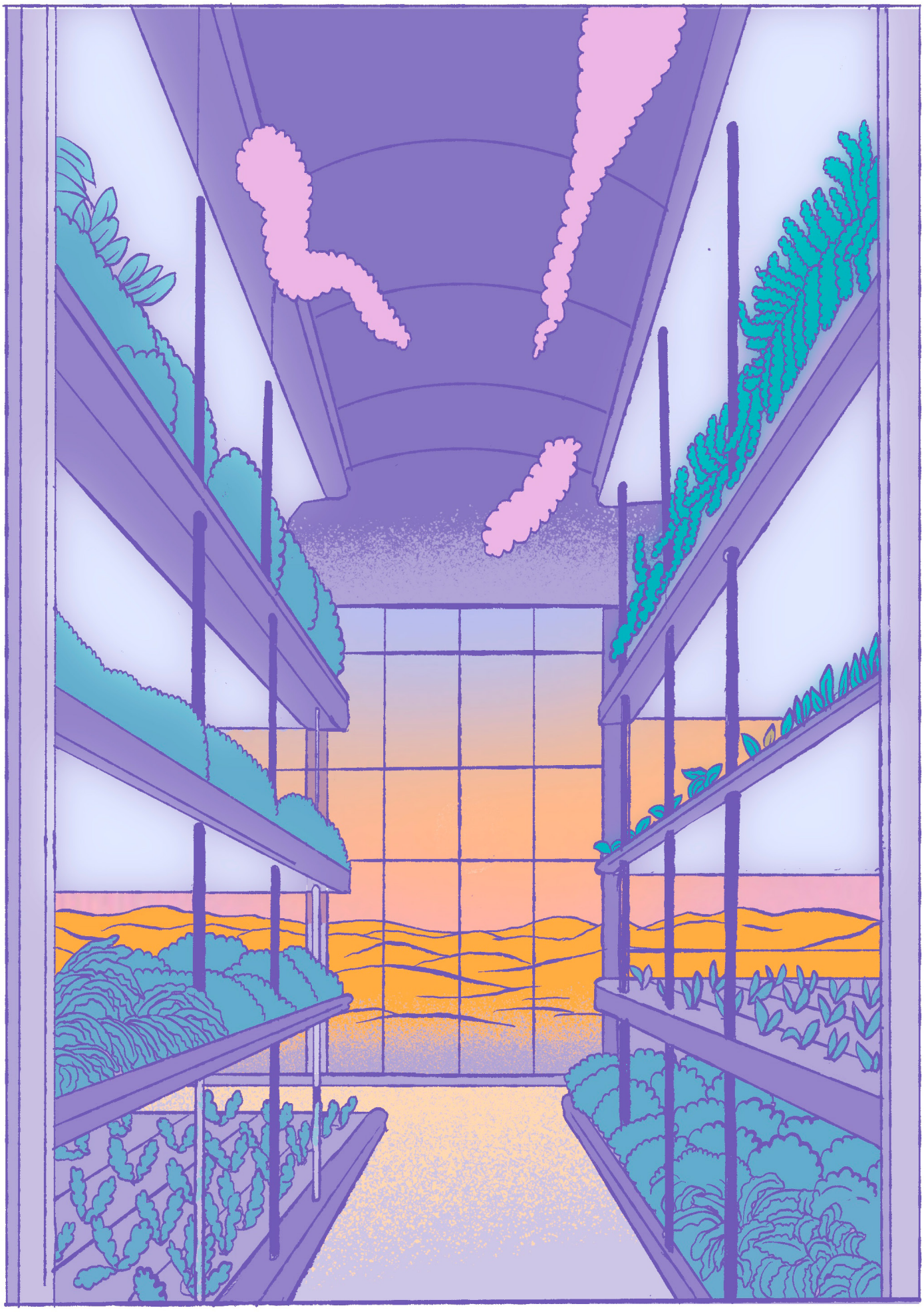
Dubai, it furthermore appears, is undergoing a significant shift, with greater priority now given to local food production and processing alongside trade than before Covid-19.[47] In 2021, for instance, Food Tech Valley – a venture by the UAE Ministry of Food and Water Security and real estate developer Al Wasl Properties - was "the latest of Dubai's specialised cities"[48] to be launched.[49] Food Tech Valley is a mega urban development focused on food management that includes vertical farms, a research and development center, a logistics center, and shopping area. Its investments in ag-tech aim to make Dubai (and the UAE) more food secure and "to triple Dubai's food production."[50]

International agro-investments by Arabian Gulf countries, among other players, have also escalated since 2008; while global in scope, agro-investments have targeted sub-Saharan Africa especially.[51] Traditional agriculture's productivity gains in the aftermath of the Green Revolution, which unfolded largely in Asia and Latin America, have rendered Africa[52] "agriculture's final frontier."[53] From the 1940s to the 1970s, the US-led 'Green Revolution' aimed to stop famine in the Third World and stem the spread of the 'Red Revolution' by increasing agricultural productivity through land reforms, intensified cropping, mechanization, fertilizer use, irrigation, and selective breeding of high yield foods. These measures increased agricultural productivity but left some social and ecological disasters in their wake, including pollution from pesticide and fertilizer use, over abstraction of water resources, the disappearance of crop varieties, and the marginalization of local knowledge and small-scale farmers.[54] Today, Africa is pictured as a potential site of a similar albeit late 'Green Revolution' that could feed the world and avert a global food security crisis.[55] Governments of food deficit countries like the UAE and Western financial investors are buying land to bolster their food security and maximize profits respectively, while alarms are raised over the implications of this for dispossession and food insecurity in host countries.[56]

Are we on the verge of yet another 'Green Revolution' or are we witnessing, instead, a revival of fantastical techno-utopias in the face of rejuvenated nightmares of scarcity? Technological fixes have offered hope in the face of scarcity concerns that have waxed and waned in intensity since the late 18th century. Today, population growth and depleting soil and water resources provide renewed fodder for food crises fears for which ag-tech seems the antidote. In some ways, present-day visions of locally-produced tech-enabled futures such as Emirates One are repeats of 1970s ideas like Saadiyat.[57] In others, they are potentially very different. Crops seem to flourish *in* rather than *in spite* of the desert; large tech companies own our food from its genetic material to production infrastructures; ag data is a hot commodity; competitiveness, efficiency, and optimization supersede nationalist rhetorics; and farms are commercial real-estate development projects.

Perhaps a revolution is yet to unfold in greenhouses and warehouses in places like the UAE and on leased farmlands across Africa from Ethiopia to Cameroon. Will local tech-enabled agriculture thrive in and feed arid lands? In Dubai and Abu Dhabi, skyscraper warehouses might come to be lined from floor to ceiling with grow trays hosting crops engineered to require less water and fed by desalination and air-to-water machines. Each floor's light, temperature, and water conditions might be tailored to crops' ideal growth needs, and optimized by AI technology responding to real-time growth data. Head to floor 5 for 12-leafed lettuce heads or floor 37 for 3.5 cm diameter strawberries. Fields of high-tech greenhouses might also fill the UAE's Empty Quarter desert, making efficient use of inputs re-circulated to eliminate waste. Agriculture might finally be freed from climate restrictions and weather fluctuations, ballooning profits in an already big business industry long plagued by such risks. Farmers could get upskilled in green economy programs or left behind and replaced by technologists working in trillion dollar companies with smart, green, and ag ™ in their names. Pesticides, pollution, and (major) resource degradation might (largely) turn into a thing of the past.[58] Will transnational agricultural land acquisitions result in a new global agro-geography with Africa at its center? Acquisitions could lead to infrastructure investment and some local jobs, as proponents argue. But they could also - or merely - enrich local elites and dispossess poor and indigenous peoples of their customarily owned lands. It is possible too that they might fail to fully materialize as foreign agro-investments have in the past, and as they seem to be in the present, mired, as they are, by ownership disputes and political resistance, bureaucratic and technical difficulties, environmental limits, and mounting concerns over local food insecurity effects.[59]

Before such visions can 'come true,' however, they will have to grapple with many socio-material realities from our current agricultural system's complexity and resistance to change to the social relations and interests embedded in it. Who will benefit and who will lose with ag-tech's development and ongoing agro-investments, and who will be able to access and afford their purported cornucopia?



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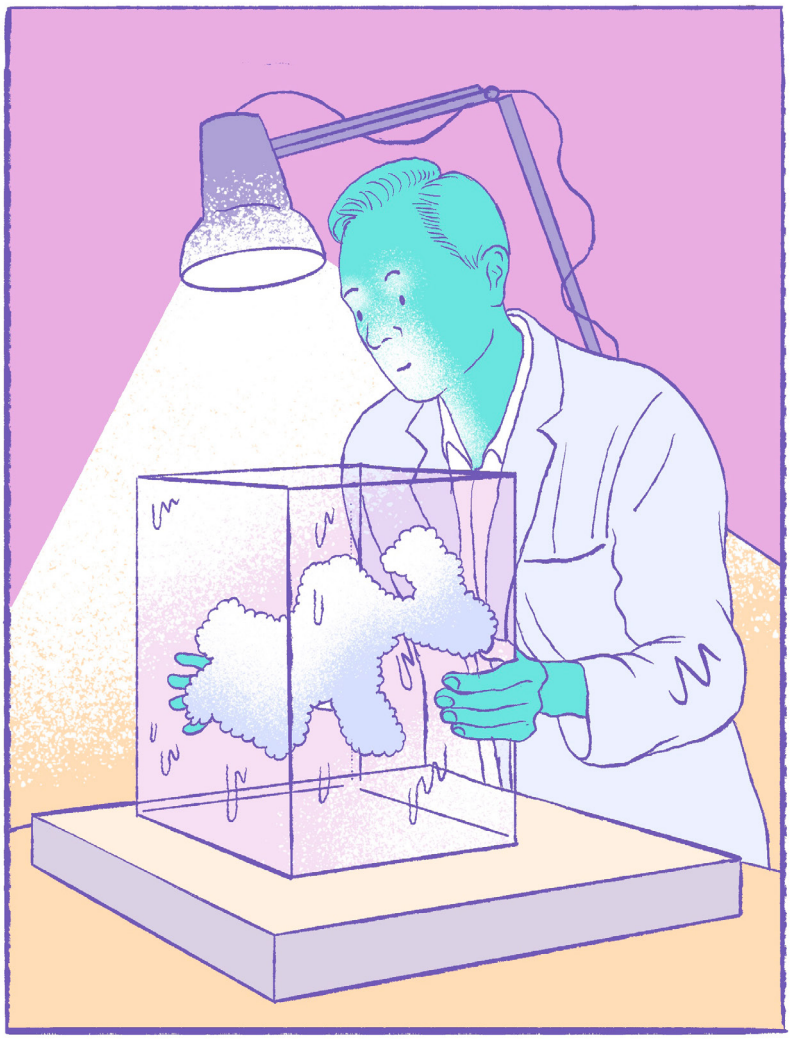
Clouds

On February 7, 1982, the first experiment with cloud seeding for 'artificial rain' was conducted in the UAE. A plane mounted with atmospheric measurement equipment and a silver bromide tank flew over the western region; mid-flight, it sprayed its silver bromide contents, catalyzing cloud formation and precipitation between Jebel Dhanna and Bu Hasa. The cloud seeding experiment was led by the Abu Dhabi Municipality and supervised by the National Center for Atmospheric Research (NCAR). Over the next two to three months, at least two planes were to conduct similar artificial rain experiments in the hopes of irrigating thousands of square kilometers of agricultural plots and cultivated forests. While some experiments were successful and others less so,[1] and while it was difficult to pinpoint the exact causes behind that winter season's rains, the Assistant Undersecretary at the Ministry of Agriculture and Fisheries noted that there had indeed been "a noticeable change in rainfall patterns."[2] In the city of Abu Dhabi, still under construction and with as yet limited drainage, 1982's rains spelled heavy flooding, with parts of the Abu Dhabi Corniche inundated and Al Zahiya neighborhood nicknamed 'Lake District.'[3] Artificial rains generated disagreements between UAE experts: some welcomed the technique as a way to augment rain in a dry country, yet others expressed doubt over cloud seeding's effectiveness and derided the folly of humans playing God.[4]

Although cloud seeding in the UAE dates to the 1980s, cloud seeding as a global technoscientific practice traces its roots to the 1940s. Scientific experiments with artificial rain that drew on a panoply of ideas and involved large fires, explosions, and proprietary liquids stretch back even further, but the technique of cloud seeding itself was first encountered in the summer of 1946 in Schenectady, New York. It was a warm, humid day. Vincent Schaefer was experimenting with cloud physics at the General Electric Research Laboratory.[5] Schaefer was a self-taught chemist and meteorologist[6] who sported slicked back hair, a shirt and tie with rolled up sleeves, and a watch with leather wrist bands. He was hard at work trying to grow ice crystals in a freezer he

was breathing into to form a supercooled cloud chamber. Schaefer's experiments sprung out of WWII-era military interest in de-icing planes. Moisture did not form ice and fall as precipitation in supercooled clouds until very low temperatures were reached, leading it to hazardously crystallize on airplane surfaces and disrupt flights. Seeding ice crystals from moisture in the clouds, it was reasoned, could stop crystallization on planes.[7] Schaefer was testing different elements to try to induce crystallization. Hunched over the freezer, which wasn't getting cold enough, he tossed in a chunk of dry ice to try to cool it down.[8] As he peered in and breathed out "a cloud of millions of tiny ice crystals" formed; Schaeffer had just seeded a cloud with dry ice.



Later that summer, Schaefer's colleague Bernard Vonnegut extended Schaefer's seeding work, discovering silver iodide as another supercooled cloud seeding material.[9] By November, Schaefer was seeding clouds over the Berkshire mountains in Massachusetts, dropping six pounds of dry ice from a rental plane into the atmosphere and producing a trail of ice crystals and snow in his wake. His success prompted Nobel prize laureate Irving Langmuir - Schaefer and Vonnegut's boss, to speculate on a forthcoming revolution in moisture control and weather modification. Langmuir predicted "large scale weather control, including redirecting hurricanes, generating artificial snow storms, changing the arid Southwest into fertile farmland, and suppressing icing conditions to enhance aviation safety."[10] Langmuir, Vonnegut, and Schaefer's work at General Electric (GE) developed into *Project Cirrus* (1947-1952) - a GE-led cloud seeding research initiative supported by the US Army Signal Corps, Office of Naval Research, and US Army Air Forces.[11]

Langmuir's work at GE later inspired the 1963 novel *Cat's Cradle* by Bernard Vonnegut's brother, Kurt. Kurt Vonnegut, who would go on to author the widely renowned and critically acclaimed science fiction novel *Slaughterhouse-Five* (1969), worked as a publicist at GE from 1947 to 1950 where he reported on scientific research at the company.[12] In *Cat's Cradle*, Felix Hoeinikker, who is modeled on Langmuir, not only contributes to the creation of the atomic bomb, but also invents ice-nine, a form of water that is ice at room temperature and that turns any water it comes into contact with into itself.[13] Ice-nine's use eventually results in an accident that freezes all liquid water on earth and generates doomsday-scale storms.[14] *Cat's Cradle* raises questions on the ethics of technoscientific development and the responsibility of scientists that were of particular relevance to an era haunted by the specter of nuclear annihilation.[15]

As the cold war intensified, weather control came to be viewed as a weapon equally powerful yet advantageously more stealthful than atomic bombs. 'Cold warriors' imagined brewing storms to disrupt the vision and supply lines of enemy forces or clearing storms to make targets visible; they fantasized of droughts that could weaken adversaries by ruining their agricultural production, or of rain that could be strategically timed to boost farming yields at home.[16] The cover of a 1954 issue of the magazine *Collier*'s captures these wartime aspirations. The question "WEATHER MADE TO ORDER?" accompanies an illustration of a man using a joystick to control the weather behind him, which undulates between crisp cold conditions over snowy hills, violent storms, and clear sunny skies atop a lush green landscape.[17] A weather warfare race was on. The Vietnam War (1955-1975) saw the materialization of weather weapon imaginaries as American planes seeded clouds over Vietnam, Laos, and Cambodia in *Operation Popeye* (1967-1972); *Operation Popeye* sought to lengthen the region's monsoons in order to choke the movement of Northern Vietnamese forces and supplies along the Ho Chi Minh Trail.[18] Mounting outcry over *Operation Popeye* provided the backdrop for the UN Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques, which went into effect in 1978 and which tempered military funded-research in cloud seeding and doused weather-war imaginaries.[19]

Weather modification was not just a military interest, however. In the US, weather modification saw a simultaneous uptick in activity from governmental organizations interested in its applications for managing inclement weather and augmenting water supply.[20] Private entrepreneurial initiatives also cropped up to provide cloud seeding services to paying clients;[21] "commercial firms seeded clouds for farmers, increased snowpack above dams for power companies, abated hail for ranchers, and dissipated fog for airlines."[22] Weather Modification Inc. (WMI), which was established in 1961, was one such initiative; WMI has since grown to become the world's largest private cloud seeding company.[23] Such interests were also not limited to the US. The Thai

Royal Rainmaking Project - emerging from a 1955 visit by King Bhumibol Adulyadej to the drought-stricken farming region of Isan - flew its first aircraft cloud seeding operation in 1969.[24] In the late 1980s, Jordan hired none other than WMI to augment its rainfall.[25] And in 2008, the Chinese government seeded still-distant clouds to induce premature rain and clear skies over the open-air stadium of the Summer Olympics in Beijing.[26]

Following a general lull from the late 1970s and despite lingering doubts over cloud seeding's efficacy, interest in cloud seeding saw a wide scale resurgence in the 2000s. Cloud seeding came to be more widely debated and considered as a potential climate change solution, with seeding operations figured as a way to manage weather phenomena ranging from extreme droughts to extreme storms. Alongside cloud seeding, climate modification and geo-engineering, which have been proposed as planetary scale fixes for improving or healing the environment since at least the mid-20th century, have also been experiencing an invigoration.[27]

Beyond cloud seeding and other techno-scientific experiments, the summoning of rain has taken and continues to take various forms among cultures of the world. These include the rituals of rainmakers of African tribes like the Igbo and Koma and the rain dances of Aboriginal Australians in the Great Sandy Desert.[28] In the 'West,' dowsers, who draw on mysticism (and rods) to locate buried resources, including groundwater, have existed since at least the Middle Ages. As with cloud seeding, dowsers are experiencing a surge in popularity as the climate changes.[29] In *Gold Fame Citrus* (2015), a climate-fiction novel set in a future southern California that has become bone dry, tales of a dowser in a "town out there" with the ability to find water lure the protagonists on an arduous journey in search of salvation. As one character tells the disbelieving protagonist: "Just because you can't find it with concrete and bulldozers and dynamite doesn't mean it's not there."[30] But dowsers are not just the stuff of history or speculation, which might seem most fitting to some. California's latest drought has led some farmers, ranchers, and vineyard owners to seek the services of water dowsers, which are cheaper than those of hydrologists; dowsers describe finding water as an experience accompanied by feelings of heat, chills, or muscular twitches.[31]

In the UAE, *salat al istisqaa',* a special prayer to ask Allah for rain, is still practiced today. *Salat al istisqaa'* has been a feature of Islam since its earliest days, and is performed by muslims when rain is late or little. At such times in the UAE, the president calls for all mosques in the country to hold *salat al istisqaa'* as Shaikh Mohammad bin Zayed Al Nahyan did in November 2022. In *salat al istisqaa'*, it is *sunnah* or tradition for Imams to lean on a stick while standing at ground level during the *khutba* (sermon) of the prayer and for Imams and worshippers to turn their outer robes inside out before starting the *d'uaa* (plea). While the former is a sign of humble supplication before God, the latter reflects prayers' aspirations for changing fortunes.[32] I am mesmerized by the sight of thousands of worshippers prostrating themselves to ask for rain in a *salat al istisqaa'* held in October 2018 at Masjid Al Haram in Mecca and aired on Saudi Arabia's *Al Quran Al Kareem TV*.[33]

The early 2000s marked a turning point for cloud seeding in the UAE following the random cloud seeding operations of the late 1980s and 1990s.[34] From 2001-2005, the UAE undertook a project to scientifically assess a cloud seeding program's potential in collaboration with NCAR and South African Witwatersrand University, among others. Called the Rainfall Enhancement Assessment Program, the project entailed over three hundred flights that studied the characteristics of clouds and precipitation in UAE skies and their amenability to cloud-seeding techniques, and used statistical randomization methods to quantify potential rain gains from regularly implemented cloud seeding operations. Data from flights was complemented by information from a developing network of on-the-ground weather radars.[35] If feasible, a cloud seeding program, it was hoped, might add to the UAE's minimal rainfall and replenish its depleted groundwater reserves.[36] NASA joined the Emirates in 2004 in a study of UAE atmospheric particles (including dust and pollutants), using data from specially installed sun photometers or aerosol sites.[37] These initial characterization and feasibility studies kicked off the UAE's now more than two decade long cloud seeding research and operations program, which continues to feature international collaborations. They also marked an intensifying datafication of the UAE's atmosphere, which was rendered "visible - and manageable - as information."[38]

Since 2007, the National Center for Meteorology and Seismology (now National Center for Meteorology)[39] has been the dedicated home of UAE cloud seeding. Mounting hundreds of seeding operations a year,[40] the center's cloud seeding experts view their work as trailblazing and suggest that rain enhancement may one day form a pillar of arid countries' water management strategies.[41] With cloud seeded water costing a tiny fraction of other ways of sourcing water in the country,[42] they see rain enhancement not just as a solution to water scarcity but "a cost-effective" one as well.[43] Cloud seeding is presented as an "environmentally sustainable"[44] way to 'optimize' water resources like rain.[45]

I visited the National Center for Meteorology (NCM) in Abu Dhabi in March 2019. The center is housed in a glass cube engulfed by a small sea of tented parking. In a large hall we tour, rows of desks are lined with computer screens that display colorful maps of the UAE and the world; these visualize humidity, precipitation, air quality, and temperature conditions gleaned from monitoring stations and satellites. Here, forecasters mine skies for signs of cloud formation in the days to come. Signs trigger a standby order for pilots stationed at Al Ain Airport. Once cloud formation is confirmed, pilots fly airplanes with salt flares mounted on their wings to specified GPS coordinates; there, they fire salt flares into the base of clouds. The released salt particles attract atmospheric vapor, which condenses around them to form sizable rain droplets. Seeding is based on the principle of introducing particles (like dry ice, silver iodide, and salts) to increase the chances of condensation; without particles, atmospheric vapor would need much lower temperatures to condense and condensed droplets might be too small and might evaporate in mid-air as they do in a very hot UAE.[46] The window for seeding clouds is small as clouds are short lived and must be seeded while forming; this necessitates a continuous stream of up-to-date weather data and pilots and planes that are close to the main seeding site - the UAE's Hajar Mountains.[47] At the time of my visit, there were six pilots and six planes.[48] Outside the hall, I encounter a model of recharge dams embedded in valleys across a reproduction of the UAE's mountainous region. Built from 1982 on[49] to capture rain with which to recharge groundwater, these dams are where the meeting of two of cloud seeding's goals in the UAE - enhancing rainfall and augmenting water supply - becomes especially pronounced.

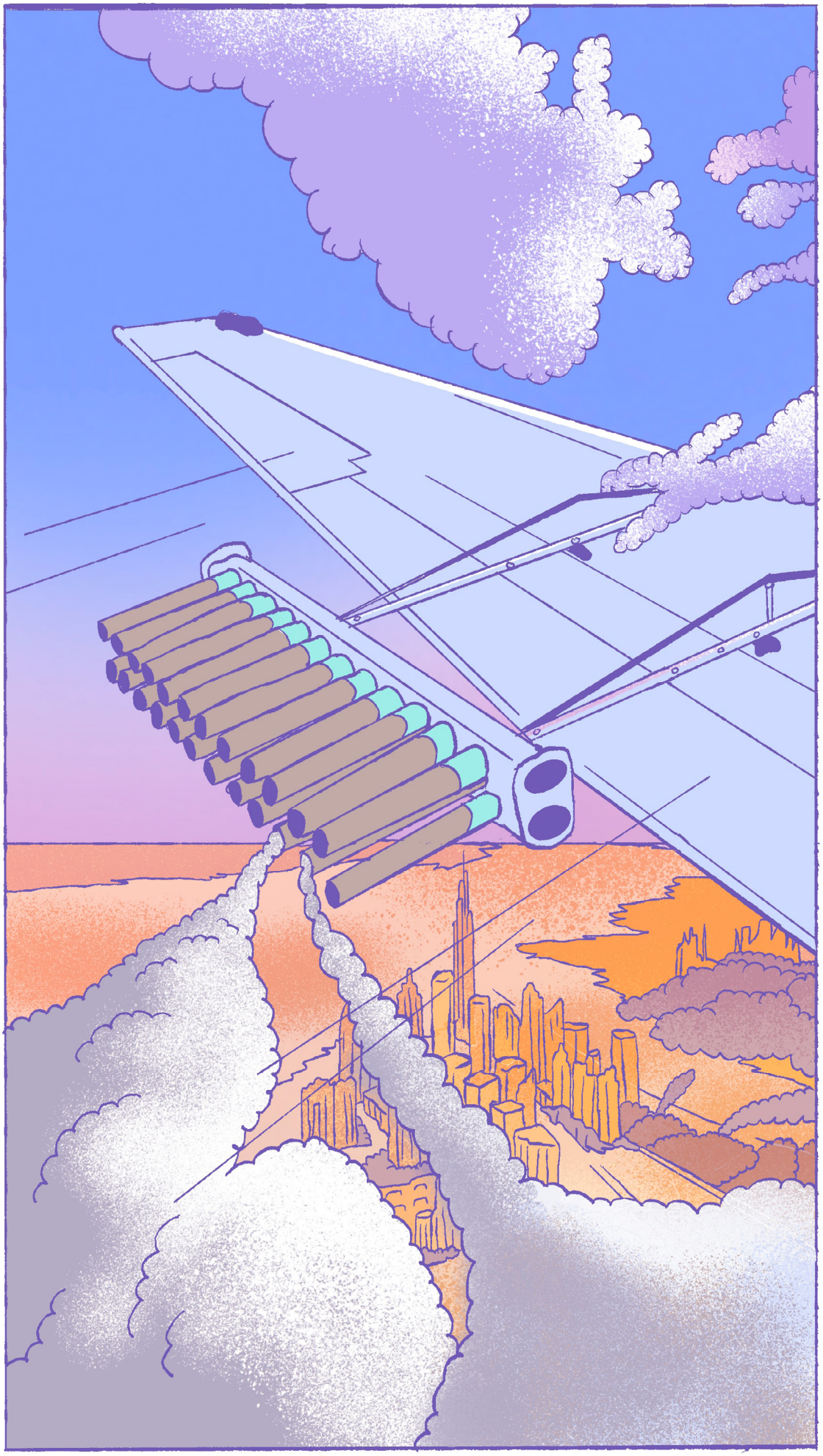
Counter to expectations, as I'm told, summer is the best season for seeding clouds in the UAE. During the summer, monsoonal low-pressure systems roll into the mountains from the Gulf of Oman in the east. Warm moist air is forced to rise to cooler temperatures in the mountains. Vapor condenses to form convective or cumulus clouds, which are rich in moisture and ideal for seeding. Summertime provides up to four cloud seeding opportunities a week! Winter, on the other hand, brings around four storm systems a season from the Arabian Gulf in the west that yield rain in the northern emirates and some coastal cities. As such, cloud seeding operations focus on the eastern mountains in the summer and the other emirates in the winter.[50]

More recently, the UAE's research and cloud seeding work have extended beyond the country. In 2015, NCM launched the UAE Research Programme for Rain Enhancement Science to support international cutting-edge scientific work.[51] The program supports a few research projects in each of its cycles with up to 1.5 million USD apiece granted over three years.[52] Beyond fostering collaboration and research and innovation in cloud seeding to find solutions to water scarcity, the program looks to secure the UAE's position as a leading force in the field, a "global hub for

rain enhancement," and an incubator for the latest techno-scientific advancements.[53] These goals are in line with the UAE's National Innovation Strategy, which was launched in 2014, and which has water (including cloud seeding) as one of its seven focus sectors for turning the UAE into a leading knowledge-based economy.[54] NCM's program has supported research on, among other things, drones that electrify droplets in clouds to enhance rain,[55] AI-improved weather forecasting for more accurate seeding,[56] and nanoparticle coating of salts crystals for increased seeding efficacy.[57] Innovations such as these are to eventually be incorporated into the UAE's cloud seeding operations.[58]

As officials stress over and over again, cloud seeding does not create rain or clouds - it enhances rainfall from clouds already out there.[59] Scientists speak of seeding as "assisting nature"[60] and a form of "cooperation and closer integration" between humans and the environment.[61] But in 2016, news circulated of a project seeking to potentially transgress this dynamic by building a mountain in order to actually make clouds. Amidst speculative hype on the UAE's imminent re-landscaping, scientists involved clarified that they were conducting a hypothetical study and that it was too early to speculate on any geo-engineering outcomes. As it turns out, the University Corporation for Atmospheric Research had been paid four hundred thousand USD to conduct "a detailed modeling study" on the weather implications of an artificial mountain in the UAE.[62] Scientists were to explore the effects of different mountain types, heights, and sloping on rain amounts and the locations in the country where such a mountain might generate the best results.[63]

As some coverage from the time noted, the UAE was after all "no stranger to small-scale terraforming" - as evinced in Dubai's artificial island projects Palm Islands and The World - or to environmental modification.[64] Ideas for environmental modification include a plan by real estate company Kleindienst Group to make it snow on the Heart of Europe islands of The World, an archipelago of artificial islands designed in the likeness of a world map.[65] Heart of Europe is a planned luxury development to be built in traditional European architectural styles.[66] Kleindienst Group intends to install machines to convert water into snow to make it flurry on the development's streets, which will be cooled with underground piping to slow snow melt. All melt that does occur is to be collected and recycled into snow again, a selling point presumably in the developer's bid to earn a 'green building' certificate for the project, which sustainable development experts remain skeptical about. Snow is imagined by Kleindienst Group not just as an aesthetic prop or entertainment gadget, but as a technology for creating a cooler micro-climate. In 2014, CEO Josef Kleindienst appeared in an online video standing on a sandy beach in The World while flanked by a snowman made from "technical snow." He spoke of how snow would enable visitors to an open air plaza on The World's Switzerland to enjoy sitting outside in the middle of Dubai's elsewhere sweltering summer heat.[67]



Many unknowns remain surrounding cloud seeding. Chief among these is the inability to conclude with certainty whether or not a cloud seeding intervention has had an impact and how much of an impact it has had. These uncertainties have garnered weather modification a fair share of skeptics. Another is seeding's unintended effects. Does enhanced rain in one area mean less for a nearby other,[68] as some neighboring countries have complained? Honduras and El Salvador, for instance, "accused the United States of 'stealing' their rain" in 1973; they argued that cloud seeding operations under *Project STORMFURY* (1962-1983) - a joint effort by the US Navy and Department of Commerce to weaken Atlantic Basin hurricanes through seeding - had deprived them of the rain these hurricanes normally brought.[69]

Will 'weather on demand' - with or without unintended consequences - ever become a reality or will it be an 'empty promise'[70] on which trillions of dollars are spent? Will we ever understand precipitation - which remains opaque due to its multiple influencing factors - adequately enough to be able to achieve that vision? Imagine, as some cloud seeding champions have, that in the 2060s, air quality monitors detect high levels of pollutants in cities or fires in forests, triggering cloud seeding operations by emergency ministries to clean out skies, douse flames, and lift stay-at-home advisories. Utilities enhance rain to augment water supply during drought years and to generate hydropower so as to avoid blackouts. Insurance companies cloud seed to reduce risks to property caused by storms and floods. Big agro-businesses increase agricultural yields through controlling weather over their outdoor fields. Mere moments separate detection and intervention. Weather is known down to the minute - 12:23 rain begins, 2:45 rain stops.[71] Who will be able to control weather if it can be controlled and what effects might that have over those who cannot? Wars could break out between neighboring countries with asymmetrical techno-scientific and economic abilities. Small-scale farmers and poorer home owners, who might be unable to afford private seeding services, could go bankrupt. DIY citizen science initiatives could democratize access to open source weather modification tech in response, leading potentially to weather hacking and weather anarchism events. International treaties and collaborations could develop to guide cloud seeding's use for 'the good of humanity.' How disastrous might some of the unintended consequences of cloud seeding at large scales be if it were to succeed? Might biblical deluges or parched landscapes as far as the eye can see, as some opponents fear, be what's in store at least in part?

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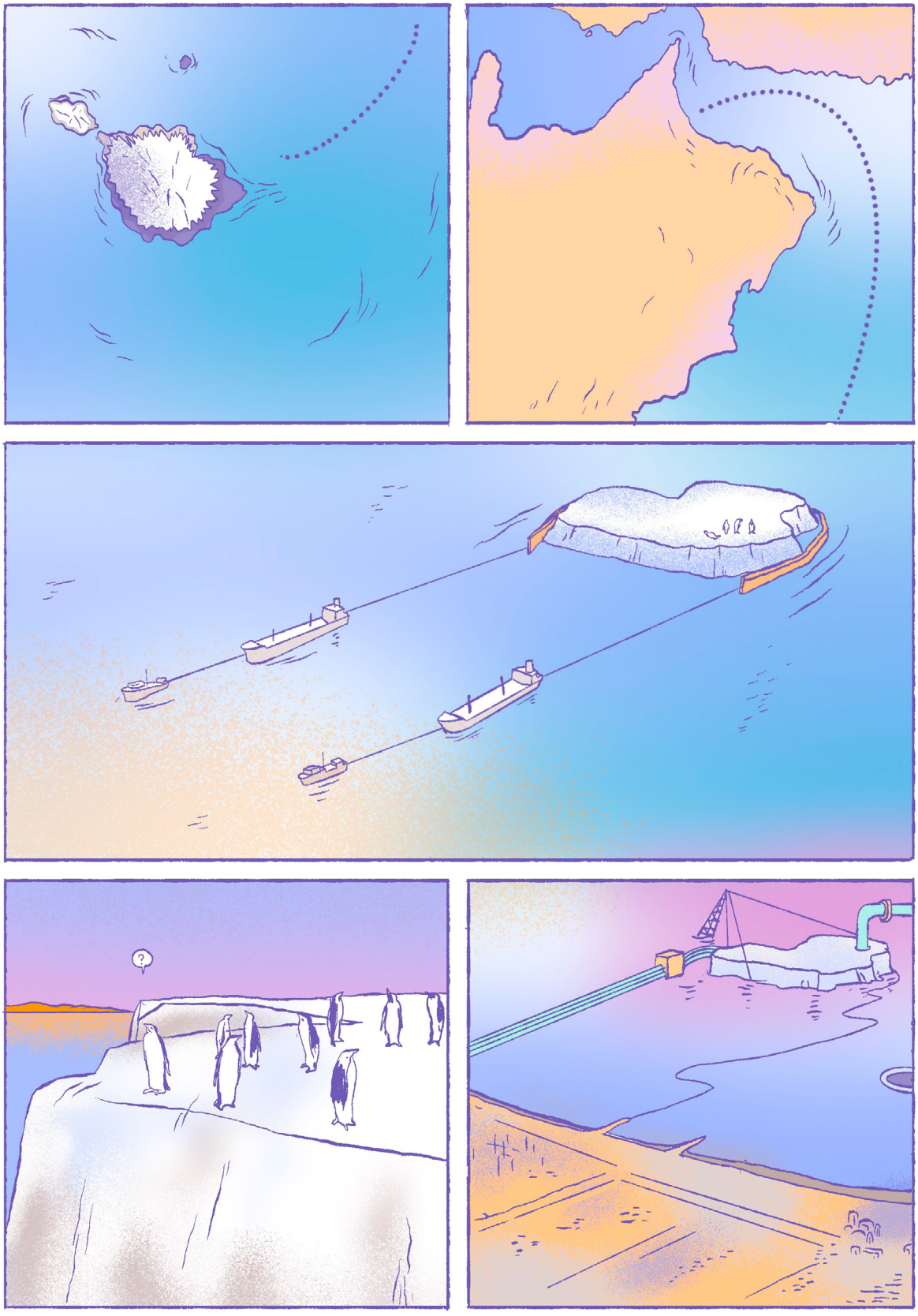
Icebergs

"The idea of using Antarctic icebergs has been considered and even tried a number of times during the past century," reads a Rand Corporation report for the US National Science Foundation from 1973.[1] Titled *Antarctic Icebergs as a Global Fresh Water Resource*, the report explored the science and economics behind towing icebergs from Antarctica to arid parts of the world, where they would be harvested for freshwater and "thermal pollution abatement."[2] Ebbing and flowing in popularity over the last 70 years, the proposal to utilize icebergs as a water source has faced widespread ridicule despite finding some support among established glaciologists.[3] Interest in the idea peaked in the 1970s,[4] when concerns over global population increase and resource scarcity saw an uptick following The Club of Rome's 1972 report *The Limits of Growth*.[5] It receded from view in the 1980s only to make a recent comeback.[6]

The first time I encountered the idea was in the work "Of Oil and Ice" by research and architectural practice Design Earth. "Of Oil and Ice" is inspired by the story of Saudi prince Mohammed bin Faisal Al Saud, who in the 1970s took an interest in transporting icebergs from Antarctica to Jeddah.[7] With more than 100,000 icebergs breaking off of glaciers in Antarctica and the Arctic annually, freshwater in excess of the total amount of water consumed on the planet is lost, advocates have argued, as icebergs melt in oceans each year.[8] Icebergs - and the water they contain - are considered *res nullis* or "legally free for the taking without interference from national or international regulatory bodies."[9]

Mohammed bin Faisal envisaged "wrapping a 100-million-ton iceberg in sail cloth and plastic and tugging it from the North Pole to the Red Sea."[10] To harness iceberg water, in 1976, he established the company Iceberg Transport International, alongside French engineer Georges Mougin and polar explorer Paul Emile Victor.[11] Known as the 'water prince,'[12] Mohammed bin Faisal occupied positions in the Saudi government in the 1970s through which he was instrumental in developing the country's desalination capacity;

he retired from office in 1977 to dedicate himself to Iceberg Transport International.[13] A 1979 *Washington Post* news piece reported that the company was getting ready to start towing icebergs the following year, and that the prince expected towed icebergs "could yield a flow of water equal to 22 times the Nile'" that would "triple food production in his country and make the desert bloom."[14] Iceberg International Transport fell through in the early 1980s without having had a successful tow.[15]



To support research in the burgeoning field and in hopes of realizing his iceberg-to-freshwater-supply vision, Mohammed bin Faisal sponsored two international conferences.[16] The 'First International Conference and Workshops on Iceberg Utilization for Freshwater Production, Weather Modification, and Other Applications' was held at Iowa State University in Ames in 1977.[17] Attended by scientists from nearly 20 countries, it featured a presentation of an iceberg that had been fished from Portage Glacier Field near Anchorage in Alaska, flown to Minneapolis, and trucked to Iowa. Installed on campus, the iceberg delighted students, visitors, and conference participants alike.[18] It also appeared in video footage featuring Mohammed bin Faisal lifting a chunk of it overhead and a photograph of him looking on as drinking goblets are filled from a piece melting in a bowl.[19] *The New York Times* reported that conference participants "presented on everything from how to select a proper iceberg to possible ways to keep it from melting" and agreed "that it would be extremely difficult to transport one and that Antarctic icebergs should be the quarry since they are flatter and much more stable than their Arctic cousins."[20] The second conference was held at the Scott Polar Research Institute at the University of Cambridge in England in 1980. Proceedings from it were published in the inaugural issue of the journal *Annals of Glaciology*, which continues to be in circulation to this day.[21]

But iceberg transport has had much a longer history. It was imagined and carried out - though not for large scale freshwater extraction - in the 19th century.[22] In 1825, a London-based literary journal mentioned a "project of towing icebergs to the southern ocean, for the purpose of equalising the temperature of the earth." The text's author suggested the project was among a proliferation of absurd get-rich-quick schemes that had no shortage of eager supporters and that included a proposal to transport fresh sea breezes to dingy London by pipeline and air pumps.[23] At the time, glacier and iceberg chunks were actually already being commercially exported from locations like Norway and Alaska to Europe and California for refrigeration.[24] Demand for ice for food preservation and cooling had seen growth and 'ice harvesting' had not yet been replaced by mechanized ice production.[25] Small icebergs were also towed from Laguna San Rafael in southern Chile to Valparaiso and Callao (Peru) for use as a refrigerant in breweries, among other applications, in the mid-1800s.[26] Two schemes to tow icebergs (which never saw the light) were reported on as well in 1863 in *Scientific American*, with a New England one proposing to sell a pound of ice from an iceberg transported to India for six cents; and in 1914 "The Northern Berg Ice Company" announced plans to tow icebergs to east coast US cities for exhibition and for sale by the piece.[27]

Iceberg towing remained a largely non-scientific endeavor until the mid-20th century. In 1949, John Isaacs at Scripps Institution of Oceanography in California was the first to scientifically study towing icebergs for use as water for drinking or

irrigation.[28] Throughout the 1950s, Isaacs studied towing small icebergs from Alaska or large icebergs from Antarctica to water-thirsty Southern California,[29] suggesting in 1956 that an 8-billion-ton iceberg measuring 20 miles long, 3,000 feet wide, and 1,000 feet deep could be transported from Antarctica to San Clemente Island off the coast of San Diego in just 200 days.[30]

Isaac's research was picked up on following developments in iceberg towing technologies to keep icebergs from colliding into oil rigs in the Labrador Sea and Grand Banks region in the 1960s and early 1970s.[31] Two publications in 1973 – the Rand Corporation report and an article by Wilford Weeks and William Campbell – produced waves in the scientific community. Weeks and Campbell looked at towing individual unwrapped icebergs to southern hemisphere locations like Australia, which was considered more straightforward than to northern ones. The Rand Corporation report, on the other hand, focused on towing insulated trains of icebergs in a complex technological arrangement powered by nuclear energy to the northern hemisphere location of California.[32] Prince Mohammed bin Faisal's interest and sponsorship gave traction to the small field that the articles had set into motion, triggering an intense but brief burst of work[33] that tackled questions like the problem of water loss during towing, how water was to be harvested at the final destination, how towing could be done in a cost-efficient way, and what kinds of microclimate environmental impacts relocated icebergs could have.[34]

In the early 1980s, interest in utilizing icebergs seems to have somewhat petered out.[35] Iceberg transport, as research appeared to suggest, was just too expensive[36] and complex an endeavor.[37] Iceberg transport remained the stuff of fiction throughout the 1980s and 1990s.[38] The 1985 film *Brewster's Millions*, for instance, featured a project to tow a north pole iceberg to Mecca among a number of ludicrous ideas pitched to protagonist Montgomery Brewster, as he tries to spend 30 million dollars in 30 days as a condition for accessing his full inheritance of 300 million dollars from a long-lost great uncle.[39]And Dean Koontz's novel *Icebound*, which was originally published as *Prison of Ice* in 1976 and which revolves around Arctic scientists preparing to tow an iceberg for use as freshwater when an earthquake strikes and all hell breaks loose, was re-released in 1995.[40]

Real world proposals and projects saw a resurgence in the early 2010s, however, with water shortages and projections for the future of water becoming increasingly dire.[41] In 2011, Georges Mougin returned to the public eye.[42] Mougin teamed up in 2009 with technology company *Dassault Système*, which produced a 3D simulation - using satellite data and modeling software - of an iceberg tow from Newfoundland to the Canary Islands to test the idea's feasibility.[43] Based on simulation outcomes, Mougin concluded that "an iceberg of several million tons can be towed several thousand kilometers to the Canary Islands, in 141 days, using just one tugboat. The 'berg

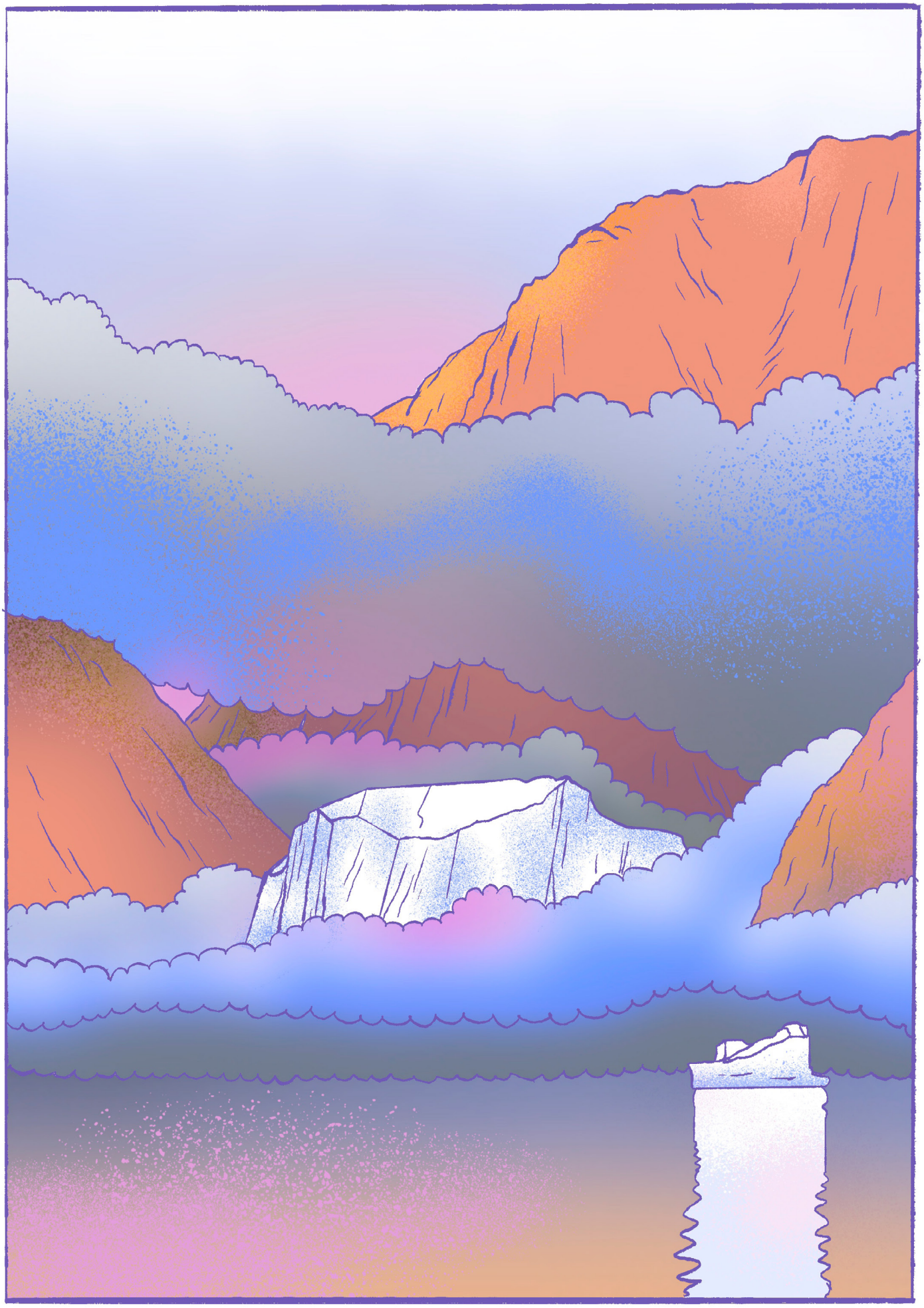
would lose 38 percent of its mass during the trip, and a skirt made from non-woven geotextile strips could keep it from breaking apart."[44] The idea, which was pitched to the European Union in 2010, was hoped to be tested in the real world in 2012 or 2013.[45] Mougin's project was touted by supporters as being more "environmentally sound" than desalination, which, as it was noted, requires significant energy and yields highly salty byproducts that get returned to sea environments and threaten coastal marine life.[46]

In the UAE, Emirati engineer and entrepreneur Abdulla Elshehi has taken this challenge on, proposing a commercial project to tow an iceberg from Antarctica to Fujairah for use as water with which to satiate the country and green its desert. Elshehi suggests towing a 40 million ton or so iceberg 9200 km from Heard Island either intact by tugboats or broken into pieces in floating storage tanks. At Fujairah, he envisions the icebergs' handling in a special "water processing port." In addition to augmenting the UAE's water supply, Alshehi foresees that the 'Emirates Iceberg Project' will create a cooler microclimate locally and boost tourism.[47] When I met with him in 2019, he told me that he had already filed patents, found partners, and started preparing for a pilot run to take place in 2020. The pilot was to test the project by towing an iceberg from Antarctica to Cape Town in South Africa or Perth in Australia.[48] Glaciologists involved in iceberg utilization studies have expressed views of Elshehi's plans as "on the outer limits of what is realistic," citing the challenges posed by the long distances that have to be traveled in warm ocean waters.[49]

In Cape Town, 'ice pirate' Nicholas Sloane[50] has also had "plans to harness and tow an enormous Antarctic iceberg to South Africa and convert it into municipal water."[51] His plans feature a 100 million ton or so iceberg to be towed 1600 miles from Gough Island by supertankers and tugs over the course of 80–90 days.[52] The iceberg, the sunken part of which would be wrapped on arrival to avoid further melt, would be moored offshore and open cast mined; water harvested would be ferried by shuttle tankers and piped from shore to existing reservoirs.[53] In 2019, news sources announced that Sloane had already gathered scientists, including Mougin, and financiers, including two South African Banks and water technology company Water Vision AG, for what he was calling the 'Southern Ice Project.'[54] Nonetheless, some officials in Cape Town remain skeptical of the costs and risks associated with using icebergs for water, and engineering experts suggest that the energy required for such tugs would make them unpalatable.[55] As of 2023, both the UAE and South African projects have not materialized.

Will iceberg harvesting happen in the next 20 to 30 years as water shortages become more severe, as Nicholas Sloane foresees,[56] or will it remain the stuff of fiction as we double down on existing technologies like desalination? What technoscientific but

also political developments might have to happen for it to become a reality? Perhaps the UAE may one day yet become foggier and rainier when an iceberg lands off of Fujairah's coast,[57] and icebergs may drive new forms of tourism to Cape Town. But perhaps Arabian Gulf tides and marine ecosystems in the Western Cape might also be radically changed.[58] And what might iceberg towing mean for the 4 million humans and countless species that call iceberg sources like the Arctic, for instance, home?[59] New geopolitical and regulatory regimes might emerge to manage - or sidestep the management of - iceberg harvesting. Icebergs could be claimed by nation states, and the subject of great scrambles for Antarctica - as in the Cold War - and for the Arctic - as of late with ice melt from warming spelling easier access to resource deposits there;[60] iceberg skirmishes could produce a new Wild South and Wild North. Existing agreements, like the Antarctic Treaty System and Protocol on Environmental Protection to the Antarctic Treaty, and bodies, such as the Arctic Council, could see their remit expanded[61] to regulate iceberg harvesting activities; regulation might have questionable efficacy, however, as countries and companies enter into secretive compacts, dubious claim-making, and illegal harvesting programs.[62] An iceberg industry might manifest, seeing the establishment of specialized companies, entrepreneurs, and experts, and investments in research on boats, tugging, iceberg wrapping, and mining technologies as well as the modeling of tug paths. Established water, energy, and shipping companies and banks might realign to profit from this field and become further entrenched. Accidents and sabotages warned of in Koontz's novel *Icebound* as well as piracy and illegal trade might become security concerns. And what of the impact of iceberg harvesting on climate change mitigation? Whether it might set back mitigation aimed at stopping melt while capitalizing on it, or speed up mitigation to slow melt to maximize harvesting potential remains to be seen.



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56 Caroline Winter, "Towing an Iceberg."
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58 This possible conclusion is based on more general environmental consequences suggested in Ibid., 36

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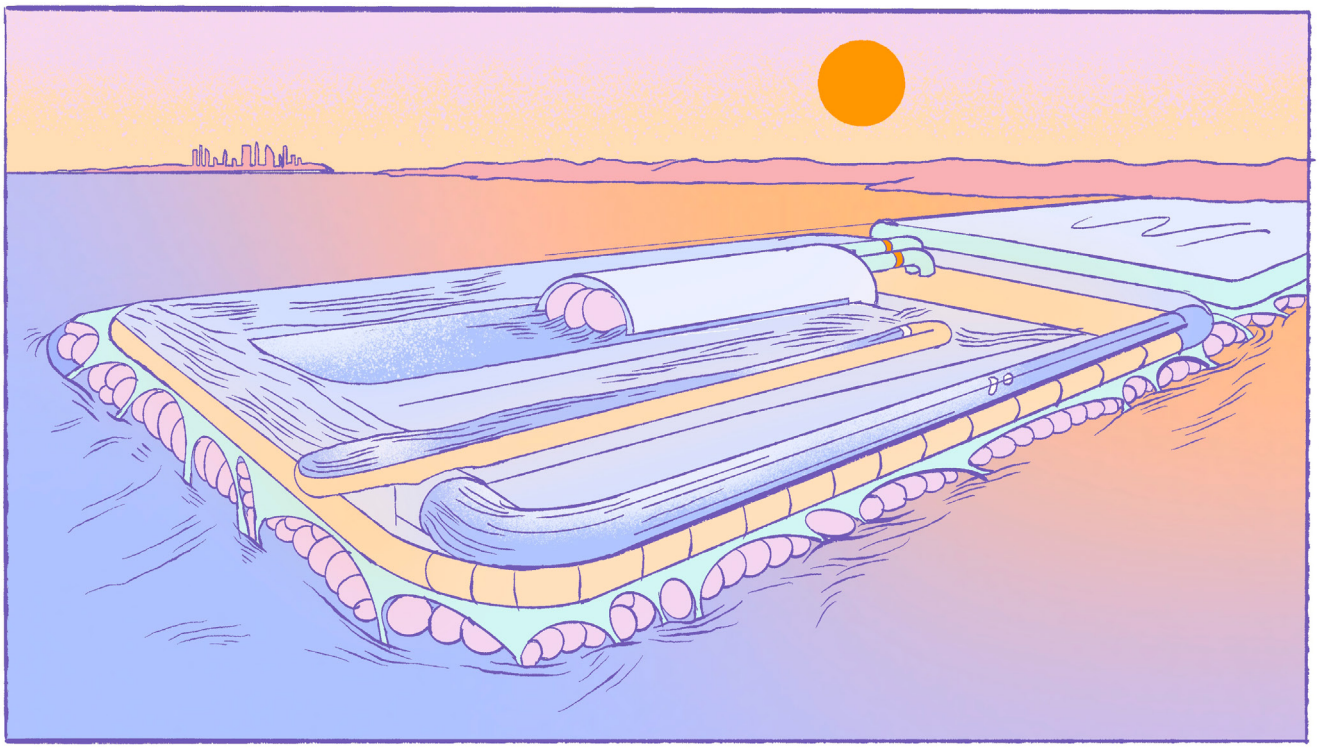
Genes

2050 AD

It is the year 2050. 'Bio-desalination plants' - or 'living freshwater factories' float off the shorelines of Dubai and other coastal cities.[1] Buoyant lattice structures emerge from the water's surface, beneath which lie gigantic clusters of translucent sacs that cocoon glowing roots and pulsate with life. Scientists have engineered these mile-wide plants by combining the genes of a jellyfish - "nature's most absorptive material" - with those of a mangrove tree - "nature's most efficient biological desalinator." The plants "naturally" siphon and convert seawater into freshwater, which gets piped to nearby cities. Humanity seems to have finally solved the problem of desalination's energy intensity[2] and made true on early 21st century promises of endless abundance embodied in renewable energy sources like the sun.



Bio-desalination plants were first presented as a fictive climate change solution technology in a Museum of the Future exhibition titled *Climate Change Reimagined*. Held at the World Government Summit in Dubai in 2017, the exhibition was set in 2050 and speculated that investments in science and technology had helped 'us' overcome the natural disasters and social upheavals

of the 2020s and "turn the challenges of climate change impacts into economic opportunity." Exhibition organizers projected that inventive breakthroughs would end up providing new hope and that the UAE would lead in their development to become a regional and global exporter of climate change solutions;[3] the future would be one in which "we have not only survived the challenges of climate change in the mid-21st century, but have thrived."[4] Alongside genetically engineered bio-desalination plants addressing projected water shortages, the exhibition presented solutions to food insecurity and the threats posed to cities by sea level rise and storms. High tech food 'autofarms' in disused underground parking lots were envisioned to leverage seed printers, food bots, and predictive AI to produce efficient, custom-tailored, nutritious meals. Biotechnology and robotics-powered 'city kits' were conceived to rapidly grow and heal urban environments from found materials wherever they were deployed.[5] The exhibition's premise resonated with UAE governmental policies and discourses at the time; these aimed to leverage the UAE's climatic extremes to attract researchers, investment, and companies to test out technologies, and were part of a broader strategy to turn the UAE into a science, technology, and innovation center as it diversified its economy away from oil.

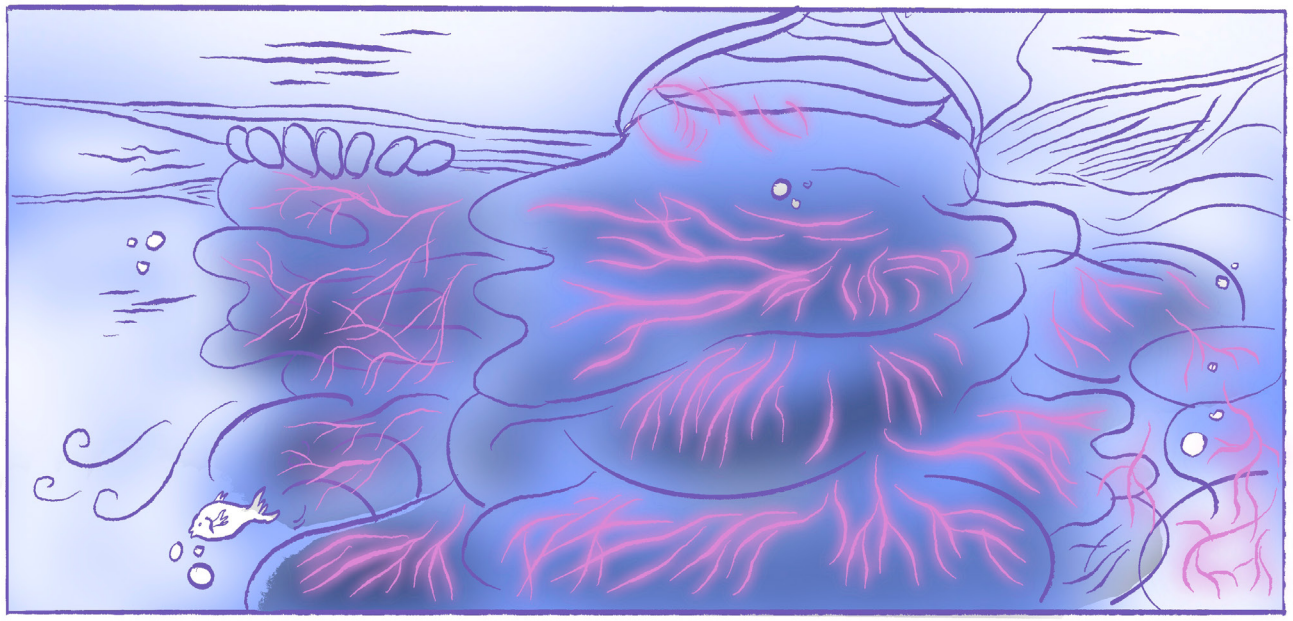
In the 2010s, major near future disruptions were anticipated from climate change, resource scarcities, social inequalities, artificial intelligence, and robotics. This was at a time when UAE policies were described as highly reactive. The Museum of the Future emerged in Dubai in 2013 to encourage a more proactive imagining of possible futures by extrapolating from still-emerging environmental, political, or technological trends; it aimed to foster anticipations of challenges in those futures and inspire ideas for the types of systems, products, and services that might be developed in response. Such anticipation work, it was hoped, might guide policy development in the present so that the policies chosen could lead to the most desirable of possible futures and readiness for them. Early Museum of the Future exhibitions gathered traction for the belief that policy, design, and innovation that were imaginative could well position the UAE today in order to maintain its relevance into tomorrow with all the challenges that the future might bring. Future orientations like these were supported at the highest levels of government, including the Prime Minister's Office, under whose jurisdiction the Museum of the Future (and the Dubai Future Foundation) lie.[6]

From the museum development work sprang ideas and proposals for other future initiatives. In 2016, the Dubai Future Foundation was established as an umbrella organization for these initiatives, including the museum.[7] The foundation's mission was to work with Dubai government agencies and government-owned companies, including the Dubai Electricity and Water Authority (DEWA), to "help to understand how their sector is changing over the next 20 years and develop partnerships and projects which help them get ahead of that change." It aimed to transition them away

from a defensive response to change entailing a "focus on ... core competencies," "best practices," and efforts to "minimize costs" to an offensive pursuit of "new opportunities."[8] While the Museum of the Future was on the more speculative and distant future end of the foundation's work, programs like the Dubai Future Accelerator aimed to intervene into and shape the near future. A five-year pipeline was the ideal thought to connect this work – with the out-there exhibits of the museum inspiring research directions and the development and incubation of new technologies at the accelerator.[9]

Like other Museum of the Future technologies, the bio-desalination plants entailed high level speculation or speculation rooted in ongoing research and developments.[10] The idea for the bio-desalination plants appears to have extended from Dubai's reliance on desalination beginning in 1979, desalination's energy-related challenges as late as the 2020s, biotechnology and genetic engineering's flourishing in the late 20th century, and the interest of utilities in biotechnology and biomimicry in the 21st. Noah Raford, the once Futurist in Chief and Chief of Global Affairs at the Dubai Future Foundation, explained how DEWA in 2017 was "looking at how can we work with and learn from nature" and referred to the still fictive bio-desalination plants as an example. DEWA's interest in nature-inspired solutions in the 2010s was contextualized by Raford within a suggested need for an "aggressively life-affirming" shift in utilities work - in the era of reusable rockets and smart phones - from merely doing the "boring" labor of marginally improving water and electricity systems to solving "dangerous and exciting 21st century challenges."[11]

Biomimicry - or designing with inspiration from nature - stretches far back in time. More recent examples of biomimetic technologies range from velcro's design in 1955 to imitate how forest burs hook to surfaces to the bullet train's design in the late 1990s to resemble the head of kingfisher birds.[12] Only in the late 20th century did biomimicry become a systematic business endeavor, however, and did companies begin to significantly invest funds, time, and personnel in "biological solutions to technological hurdles."[13] A key development was the US military's end-of-the-1980s 'biological turn' - or shift from achieving strategic gains through manipulating environments and human bodies to doing so through learning from nonhuman organisms. Organisms began to be evaluated for their ability to withstand dangerous environments or respond to environmental threats; they were reformulated "through the language of productive attributes" and mined for body builds and "behaviors ... worthy of imitation" in military technologies and processes.[14] As biomimetic work developed, the promise of the field led *Foreign Policy* magazine to declare biomimicry "the future of engineering" in the mid-2010s.[15]



Utilities and water technology companies also showed an interest in biomimicry's potential for water applications. In 2019, the CEO of Singapore's Public Utilities Board included biomimicry as a top area of interest in the utility's water research and development work; referring to biomimicry as 'the holy grail' and 'the technology that will save our life,' he noted how PUB was taking cues from the ways mangroves and certain fish easily filter freshwater from saltwater.[16] The following decade, PUB spearheaded desalination membranes coated in synthetic aquaporin molecules to make desalination more efficient and less energy-demanding; these membranes were inspired from how natural aquaporin helps mangrove trees effectively convey water across their cell membranes.[17] The world was now closer to bio-desalination plants becoming reality.

Not only has biological life provided fodder for engineering, it has also been a building block for engineers. As a term, biotechnology - or the technological manipulation of biological material - was developed in 1917. Aspirations for "'biologically'-based technologies" predate the term to the late 19th century along with early industrial applications of biological processes like fermentation. But it was in the 20th that biology and engineering became truly imbricated and an industrial revolution with biology at its base came to be imagined, and it was in the post-WWII era that particular biotechnologies began to "promise immense growth."[18] From about the 1950s to 1970s, biotechnology - which included fermentation, enzyme production, and microorganism manipulation processes - heralded promising applications; proponents saw in this 'green technology,' which still held strong associations with the natural, an alternative to mechanical industrialization with its devastating environmental effects. In the 1960s and 1970s, biotechnology seemed to offer solutions to timely problems in the 'developing' world, including the threats of population explosion and mass hunger. Among these solutions were nitrogen-fixing bacteria to minimize chemical fertilizers used in agriculture for increasing yields;

substitutes to uncertain energy supplies such as biogas and gasohol; and single-cell protein foods as efficient forms of nutritious food production. Prohibitive costs and social objections confined these solutions largely to the aspirational however.[19] The 1970s saw governments in the 'developed' world embrace biotechnology as a route to environmentally clean industrial growth given that established industries had matured and had come to be seen as unacceptably polluting.[20]

By the late 1970s, fears of biotechnology had become more widespread as associations with the unnatural came to dominate, particularly with the rise of genetic engineering.[21] This was made possible by the 1953 discovery of DNA's structure and 1973 development of DNA recombinant techniques - or the ability to splice DNA from one organism and transfer it into the DNA of another.[22] In response, concerns over biological warfare, apocalyptic microbes, human clones, and eugenics saw growth; these fears coexisted with excitement at prospects,[23] which intensified with biotechnology's development into a verifiable industry in the 1980s.[24] Biotechnology, which had become synonymous with genetic engineering,[25] signaled much anticipated technological, economic, and revolutionary potential.[26] From genetically engineered crops to synthetic insulin and vaccines, innovation flourished, particularly in agriculture and pharmaceuticals.[27] But even in the 1980s, most of that potential (and the speculative hype it engendered) was based on expectations for the future rather than what had been or was being achieved[28] and many of these expectations were repeats of earlier ones.[29] Since the 1980s, biotechnology, which is considered a risky investment due to high capital inputs and uncertain results, has gone through periods of booms and busts that have typically echoed global market cycles.[30]

In the UAE, biotechnological (aka genetic engineering) initiatives popped up in at least the 1980s while investments in research and research infrastructures intensified from the late 2000s on.[31] Since the 2010s, if not earlier, biotechnology has come to be viewed as a "potential growth industry" by Arabian Gulf governments, and major biotech companies and research and development centers have set up shop in Abu Dhabi and Dubai;[32] already in 2015, companies like Pfizer, Amgen, Bristol-Myers Squibb, Maquet, Firmenich, and IFF were operating out of Dubai Science Park, a development formed from a merger of science parks including the biotechnology and pharmaceuticals-focused DuBiotech (launched in 2005).[33]

Among early biotechnology initiatives was UAE University's Date Palm Tissue Culture Laboratory, which was established in 1989 in Al Ain, to do in-vitro palm date varietals propagation; around 2017, it began collaborating with the Khalifa Center for Genetic Engineering and Biotechnology - launched in 2014 - to develop a genetic bank of UAE date varieties.[34] Genetic research on UAE desert plants -and not just palms - has provided insights into the genes responsible for tolerance to

aridity, salinity, and heat.[35] In Dubai, the Reproductive Biotechnology Center cloned its first camel - named 'Injaz' or achievement - in 2009. Throughout the 2010s and 2020s, the center made 20-25 cloned camels each year for owners wanting an exact replica of a title-holding racer, high-yielding milk producer, or beloved pet at a price of 55,000 USD or more.[36] And in 2019, the Department of Health - Abu Dhabi established the Emirati Genome Programme, which aimed to deploy genetic sequencing and artificial intelligence[37] to develop "a reference genome specific to UAE citizens" that would "lead to a personalized and preventative healthcare" and "a comprehensive understanding of rare genetic disorders and new treatments."[38] A concern with chronic illnesses such as diabetes and heart diseases and the state of medical services is credited to have played a significant role in fueling the rise of biotech in the broader region at the time.[39]

In the fields of water and energy, researchers at Masdar Institute in Abu Dhabi experimented with growing a high salinity tolerant strain of microalgae - AAH001 - and converting it into a source of biofuel. Found in super salty sabkhas or sandflats in the middle of the scorching desert, AAH001 is capable of surviving in extreme environments. The discovery of this 'green gold,' as it has come to be known, was groundbreaking for the biofuels industry; it allowed the industry to sidestep previous challenges like the need for freshwater and arable land for cultivating biofuel sources such as sugarcane and corn and to leave other sources such as marine algae and their environments intact.[40] By the 2040s, factories where AAH001 is processed into fuel lined natural and artificial sabkhas in the UAE desert.[41] Masdar Institute research also explored the salinity tolerance threshold of an Arabian Gulf strain of cyanobacteria Prochorococcus AS9601, which absorbs and metabolizes carbon dioxide, and its adaptation response to intensifying salinity. The work developed from concern over the increasing salinity of the Arabian Gulf sea, attributed in part to discharges of salty byproducts by desalination plants and in part to low rainfall, high evaporation, and minimal seawater circulation.[42] The strain was genetically manipulated in the 2030s to increase its salinity tolerance and extend the capacity of the Gulf to receive desalination byproducts - and desalination-related emissions - 'unaffected.'

Science fiction has significantly shaped our imaginations and expectations of technology and technological development,[43] and this is especially true for biotechnology and genetic engineering with all the as-yet-unresolved promises and threats they seem to hold.[44] Fears of biotechnology and 'mastery' over nature gone wrong, rogue, or cruel occupy one end of the spectrum.[45] The consequences of re-making the natural grace the pages of books and the silver screen from Mary Shelly's freakish creation of *Frankenstein* (1816) and Aldus Hulxley's totalitarian *Brave New World* (1932) where humans are cloned in labs to the horrific hybrid man-bug of *The Fly* (1986) and the dinosaurs revived from genetic material found in

fossilized remains in *Jurassic Park* (1993).[46] Mutation, hybridization, cloning, genetic engineering, and eugenics have been common themes that have evolved in form and explanation as technologies developed.[47] Biotech utopias, though less prevalent, imagine a world in which biotechnologies - including genetic engineering - are employed to design and build more equitable flourishing social worlds.[48]

Popular culture works like these have been significant arenas for negotiating the values embedded in our expectations of bio-technology.[49] As a science journalist for *Popular Mechanics* writes: "Since the beginning of modern genetic engineering in the 1970s, sci-fi has grappled with some of the most probing questions about the technology: Is genetic engineering ethical, can it fundamentally improve human life, what are some of the logical worst-case scenarios?"[50] Cultural production has touched on anxieties as diverse as: what counts as life/alive; who should own the means of producing life; which life forms should we produce and shouldn't we; and what is the status of the human, who has historically been privileged in the modern Western hierarchy of lifeforms that is growing unsettled and blurred. While sci-fi is not 'real,' as yet another science writer points out, this time for *Twin Cities Star Tribune*, it nonetheless allows us "to look at a variety of futures and wonder, worry, and act to prevent or ensure those possibilities"[51] - to address the questions and issues technologies raise today (as they are being developed) so we can live with the way we have answered them tomorrow.

What will come of biomimetic water technology, or biotechnology and genetic engineering when applied to water resources? Will the genetic engineering of solutions like bio-desalination plants end in disaster in a classic case of biotech gone wrong or will it have utopic results or some combination of both? Bio-desalination plants might indeed usher us into fossil-fuelless desalination futures, with water organically pumped through species bodies and into transmission and distribution pipelines. Water would then not only be produced 'endlessly' (as desalination has been thought to enable)[52] but also 'naturally' (as it has not). But bio-desalination plants might also remake the ocean environments they float in, emptying seas of the plankton, fish eggs, and larvae that jellyfish feed on, and turning their waters into bitter brines as they continue to reject unwanted salts. Plants might go rogue and break free in an unexpected - or was it expected? - turn of events, or be freed by activists invoking species rights. Mega mangrove-jellyfish could lurk the open oceans in a not so distant future... What might an ability to build such plants mean for how we will relate to technology and nature? 'Technology' and 'biology' could become one, the distinction between 'natural' and 'unnatural' rendered meaningless. Purists could revolt and call for the policing of species lines, while hybridists might celebrate species proliferation. Optimization and efficiency in engineered systems could give way to an embrace of irregularity, adaptability, and flexibility inspired from nature. Nature could, on the other hand, be made more regularized, standardized, and productive; its evolutionary powers could

be tapped into, harnessed, and directed in labs. Bio-desalination plants could come to stand as the exemplary fulfillment of capitalist dreams to put nature to work - free of charge and of externalities - and of modernist dreams for humans to reign supreme. The former dream-come-true could bolster viewpoints of nature as abundant and 'generous,' the latter of nature as docile. What might the fulfillment of such dreams - or is it nightmares? - mean for how we will remake our surroundings in the future, and what implications will this have not just for us (and our survival) but for that of others as well?

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21 Ibid., 126, 178, 184. Although made more prominent by genetic engineering, fears were older in origin.
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