The National Water Management Project

Proposal for a national flood and drought mitigation system in the U.S. to combat the increasing costs and devastation of Climate-Change-caused disasters

PlanetPOV

The National Water Management Project

Damage Mitigation For Climate Change: Water Management to Reduce Flooding Events and Increase National Supplies of Potable Water

OVERVIEW

This proposal seeks to lay out a multi-stage approach to mitigating some of the most damaging effects of Climate Change, related to flood and drought events that severely impact the lives, homes, farms and businesses of a majority of Americans. In that pursuit, a national water management system is proposed.

It is not possible at this time to blunt all of the destructive impacts of Climate Change on the U.S. without reversing it globally so the goal of this proposal is to focus on meaningful reductions of the mounting damage, injuries and costs to our nation caused by intensifying storms, droughts and other water shortages. This project is envisioned to help reduce the amount of damage incurred by Americans from these destructive events while expanding the window of time that world governments have to restrain and reverse of the causes of Climate Change.

The following statement appears on the United Nations' website:

Water is the primary medium through which we will feel the effects of climate change. Water availability is becoming less predictable in many places, and increased incidences of flooding threaten to destroy water points and sanitation facilities and contaminate water sources.

In some regions, droughts are exacerbating water scarcity and thereby negatively impacting people's health and productivity. Ensuring that everyone has access to sustainable water and sanitation services is a critical climate change mitigation strategy for the years ahead.

This proposed system would help the U.S. to minimize damage from flooding and droughts, save lives, reduce increasing federal costs and resources dedicated to addressing Climate Change disasters, help protect sanitation systems, increase supply and storage of potable water, increase water conservation and help support water availability for farming and agricultural production. If the implementation of this project proves effective in this country, the U.S. could subsequently collaborate with other nations to help institute similar programs, an effort that would greatly benefit the U.S. in promoting greater stability abroad and help prevent global upheavals from the suffering, conflicts and mass migrations caused by climate-related disasters.

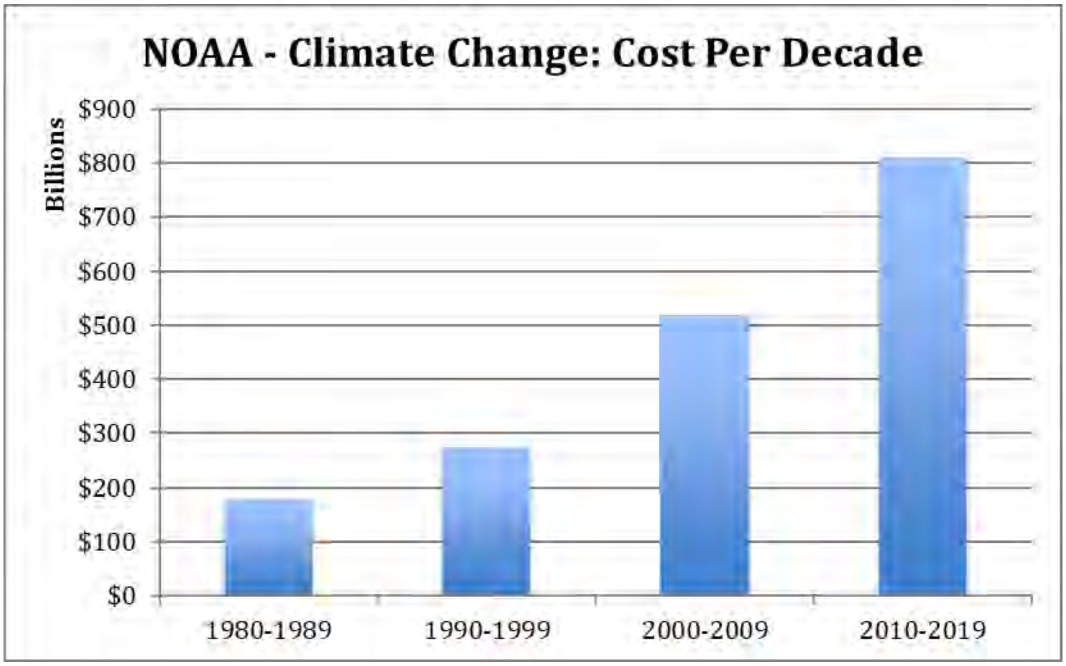
States will be equipped with enhanced, high capacity storm drain systems. Water diversion systems will be constructed to lower bodies of water before and during strong storms and that fresh water will be diverted to underground water storage facilities. Desalination plants will be built in coastal states to provide a reliable, ongoing supply of fresh water for use and storage.

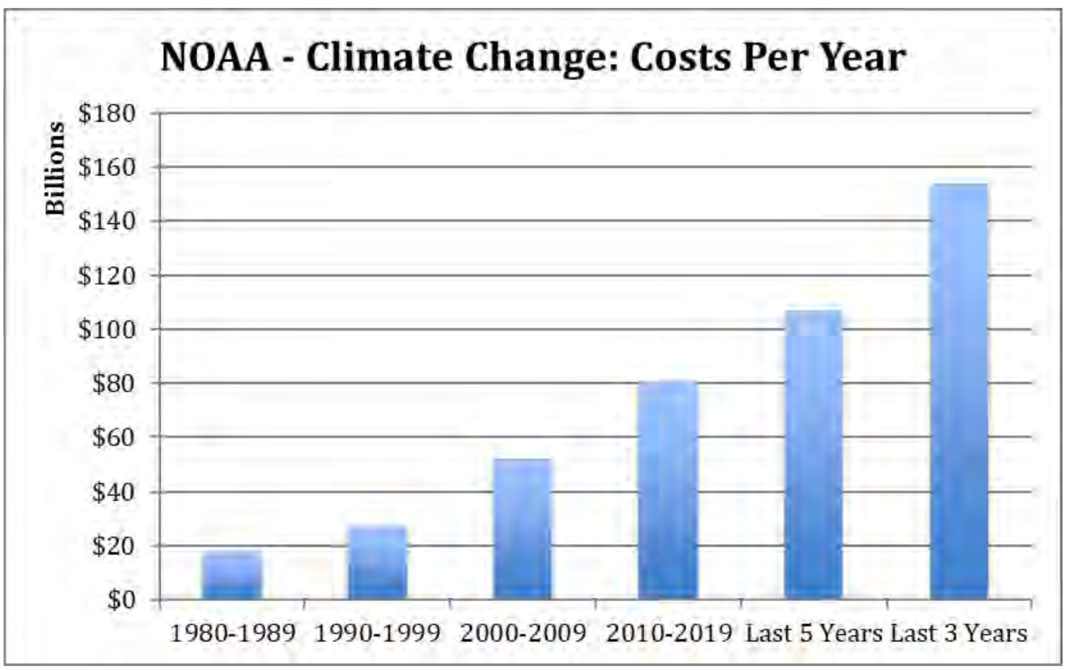
States may use the water that they generate and store to first address their own drought events while an interstate water pipeline system is completed. Then, when a state isn't experiencing a drought event, the water can be sent to states in that region that are. Some states in the south, northeast, and east coast that are less likely to experience droughts will be reliable and substantial contributors to this national water supply.

According to the National Oceanic and Atmospheric Organization (NOAA), over the previous three years, from 2016-2019, the costs of weather and climate disasters have averaged $153.6 billion per year, 60% higher than just the five-year average. If the cost of Climate Change continues to rise this steeply from year to year, the U.S. will soon be burdened with per decade costs nearing $2 trillion and rising. This is unsustainable and argues powerful for the logic of investing a far smaller sum in the Climate Change damage mitigation that a sustainable national water management system would provide, lessening the devastation and costs of severe flooding and droughts.

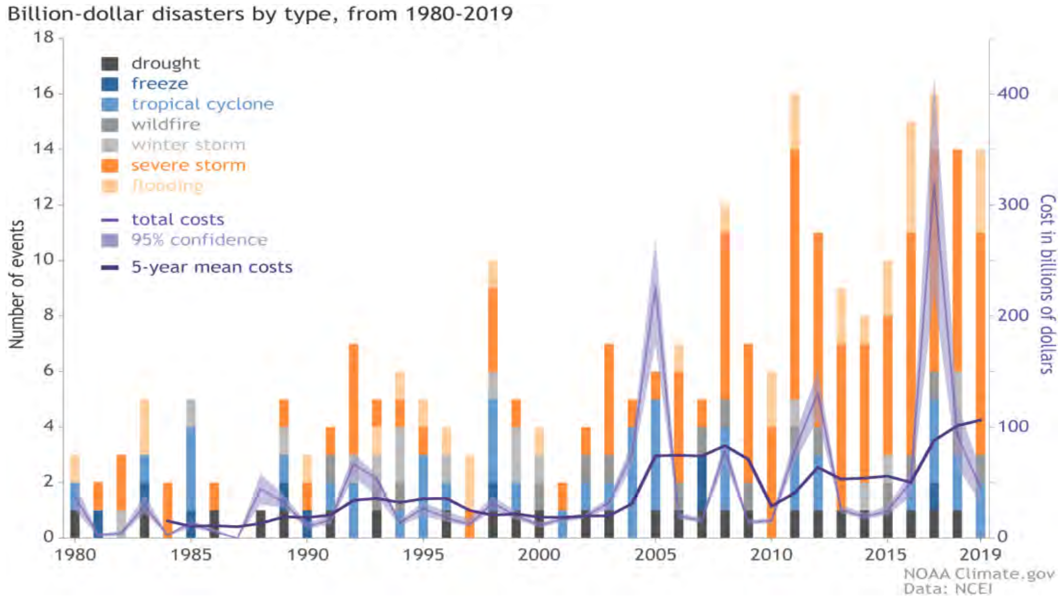
I. THE ISSUE: SKYROCKETING COSTS FROM CLIMATE CHANGE INTENSIFIED FLOODS AND DROUGHTS

According to NOAA, the last decade of Climate-Change-related damages and costs, from 2010 – 2019, reached $810.3 billion. This is up 64% from $518.1 billion in the previous decade (2000-2009). Below is a graph using the data from NOAA of the costs incurred in the past several decades.





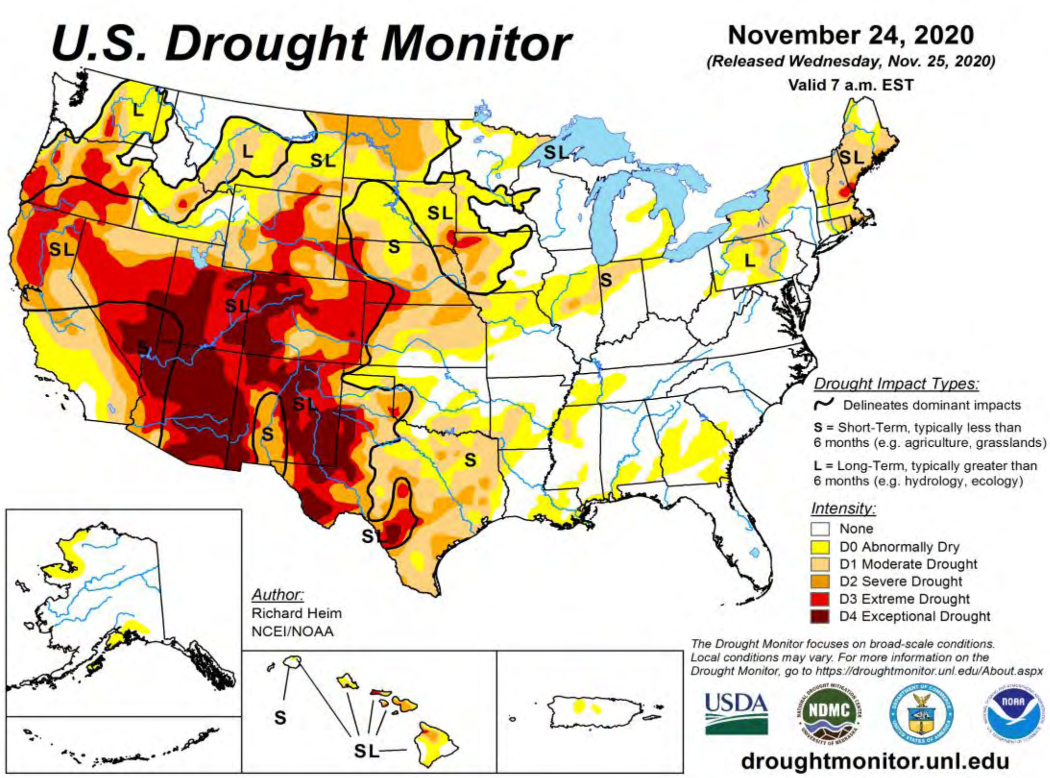
To put this increasing cost in perspective, the combined cost of all of the Climate Change disasters in the U.S. over the past four decades totals $1.78 trillion. We are now looking at the possibility of matching or exceeding that four-decade total in just one decade, the upcoming one, with no end to exponential increases in sight.



While the damage from intensifying droughts are more difficult to fully represent to the public, their destruction to the economy and human lives are increasingly widespread and profound, as described at the U.S. government site, https://www.drought.gov/drought/:

Since 1980, the U.S. has sustained 258 weather and climate disasters where the overall damage costs reached or exceeded $1 billion (including adjustments based on the Consumer Price Index, as of January 2020). Among these, 26 droughts cost the nation at least $249 billion, with an average cost of more than $9.6 billion incurred during each event. Only hurricanes were more costly. The cumulative cost for all 258 events exceeds $1.75 trillion.

The latest map reflecting the current drought conditions in the U.S.:



II. PROPOSAL: CREATION OF THE NATIONAL WATER MANAGEMENT AGENCY

It is proposed that the U.S. government creates and funds the National Water Management Agency (NWMA) that will be tasked with implementing and managing a program to protect the American people, their property and taxpayer money by mitigating Climate-Change-enhanced floods and droughts.

III. SOLUTION: FOUR STEPS FOR MITIGATING FLOOD AND DROUGHT DAMAGE

Stage One: Reduce Flooding of Cities and Enhance Water Conservation

The U.S. government, with the support of state and local agencies, shall finance, construct and otherwise provide funding for ongoing operations of new or enhanced flood control facilities including flood water pumping stations and related infrastructure in flood prone cities and regions. When the arrival of substantial storms are expected, pumps shall be activated in advance to reduce the volume of nearby lakes, rivers dams, levies and other bodies of fresh water that have histories or likelihoods of overflowing or failing. Once a local underground water storage facility is constructed (as described below), this water will be routed to it for storage. At such time, a citywide rainwater harvesting system shall be installed on federal, state and other public property and activated during events of excessive rain, also piped into the underground water storage facility. Storm drain systems shall be improved to transport greater volumes of water and be equipped with pumping stations sufficient to speed the removal of excess water from cities. Additionally in this stage, incentives for Americans to replace household appliances such as toilets and water heaters with water efficient appliances as well as incentives for farmers and agricultural entities to conserve water shall be substantially increased.

Stage Two: Underground Water Storage

Large subterranean water storage facilities shall be constructed as retention sites for water diverted from lakes, rivers, etc. in cases of flood mitigation, rainwater collection and desalination (described below). These storage sites shall be federally financed and owned but dedicated first to addressing drought conditions in the states in which they reside before providing water to drought-suffering states in that region.

Stage Three: Desalination Plants

Federally owned desalination plants shall be constructed in costal areas around the U.S. with a greater presence in coastal states that have or are near other states that have historically suffered water shortages and droughts. As energy use for desalination plants is an issue, plants shall integrate production of renewable energy into their construction to serve at least 25% of their energy consumption. Plants shall also be constructed in a manner to allow for transitioning to newer, faster and less energy-demanding technologies for desalination, such as graphene and other developing membrane filtering, as it is proven to be effective and dependable.

Stage Four: Local and National Pipeline Distribution System

A national water pipeline system, using existing easements for oil and natural gas pipelines to speed approvals and minimize impacts on private property owners, shall be constructed. Pipelines will first be built intrastate so a state can serve its own communities that suffer droughts, if any. Otherwise or subsequently, pipelines will be built to connect to states in that region that experience droughts or water shortages. When a state that stores and/or produces water is not in need of water due to drought, as prescribed in the initial NWMA Agreement, or has more water than needed to address it, water generated or stored through this system shall be contributed to other states immediately in need of water. If more water is produced by the NWMA system than is currently needed by any other states in a region and exceeds the minimum required to be retained in facilities nationally, or if otherwise agreed, a percentage of water shall be utilized to help refill natural underground aquifers (requiring construction of injection wells), dams and any other needful water storage resources around the country.

Lastly, pipelines will be built connecting regions in a complete circuit to allow for the transportation of water nationally, while continuing to respect the prioritizing of intrastate, regional then national.

Another concurrent aspect of this stage will be replacing lead pipelines in the country whether or not they are connected to regional NWMA systems.

The National Water Management Agency shall collaborate with all states to determine a fair economic structure including federal subsidies to be applied to states on the balance of their contributions and receipt of water through this federal collection and distribution system.

IV. BENEFITS: THE NATIONAL WATER MANAGEMENT PROGRAM

Reduction of Climate Change Damage and Costs

The largest underground water diversion and storage facility in the world, which is in Japan and referred to as the Metropolitan Area Outer Underground Discharge Channel, was used to contain 19 million cubic meters of water during a major typhoon in 2015 which translates into 5 billion gallons of water. It is easy to consider how much damage was mitigated by diverting that massive amount of water from Tokyo. To add some perspective, this amount of water from a single severe storm, is equal to the total water usage of Wyoming, Montana and Oklahoma combined for more than 20 days. Helping mitigate damage to cities from flooding while distributing such extraordinary amounts of potable water (after processed through a destination's local filtration plants) that continue to be generated throughout the year from flood prevention and constant desalination would also substantially reduce on an annual basis, billions in costs from increasing water shortages and persistent droughts that are pervasive in the western and southwestern U.S.

The construction of desalination plants should be recognized initially for their national security implications, assuring supplies of potable water now and into the future as Climate Change continues to reduce supplies of potable water in the U.S. and globally.

The entire national pipeline system will take a number of years to complete though its initial construction shall be to connect water storage facilities to pipelines within a state to serve its own drought-prone areas first. Then, the pipeline system will be connected to neighboring states in that region that have histories of or are currently suffering drought conditions. The government's savings on drought costs as pipelines expand will help mitigate the expense of continuing and completing pipeline construction until it connected nationally.

The damage to a single city such as Houston in just its last major storm, Hurricane Harry in 2017, cost $131.3 billion and 103 lives. Hurricane Florence in 2018 is estimated to cost $19 billion in North Carolina. The CBO states that the average annual economic cost of hurricane damage alone in the U.S. from wind and flood damage (though most hurricane damage is due to flooding) is $54 billion. According to Drought.gov, over the past five years, the U.S. has incurred an average of $106.3 billion per year in costs due to droughts.

A network of robust flood diversion, water storage and pipeline facilities as proposed here, built for a fraction of the cost of damages from a single hurricane and drought season, would not only save valuable lives but would mitigate enough in billions of disaster costs within several years of full operation to pay for the entire system and mitigate many times more that amount in costs to states and the national economy as well as strengthen our national security and infrastructure.

Employment

As a major infrastructure project in the midst of a persistent COVID-19 pandemic, along with the impact of a nation still reeling from record job losses and income reductions, The National Water Management Project will provide thousands of well paying jobs throughout the nation that will be available to a non-exclusive and wide variety of American workers. Some of the jobs created will last many months or years, others related to operation and maintenance of the system will be permanent. These jobs will also be an ideal conduit for retraining workers who have been displaced by industries with diminishing employment such as coal mining and other fossil fuel businesses, manufacturing, etc. Such workers will also bring transferrable or tangential skills, which will help speed their transition to their new jobs and the completion of this project. The employment aspect of this project addresses many current and concerning issues for Americans, unrelated to Climate Change directly, including gaining employer-based health insurance, curbing a percentage of current or impending evictions and foreclosures, increasing expendable income in working class communities that will be spent on and strengthen local businesses and increasing state and local tax revenues.

Business Development and Growth

Areas that experience severe floods and droughts are also negatively impacted when it comes to decision-making by investors and businesses that are creating or expanding operations. Stability is an important factor in choosing a location for establishing businesses, as are concerns of prospective damages and disruptions. By mitigating Climate Change damage and supporting water availability, states and cities that have been most affected may become more competitive and successful in building diversity and confidence in their economies, jobs and revenues.

V. POTENTIAL OBSTACLES: LOGISTICS AND ENVIRONMENTAL ISSUES

Logistics of Construction

The construction of desalination plants will require a search for, acquisition, local government and environmental agencies permitting of coastal land for this purpose, which could entail a considerable amount of time and legal expenses. As described above, to expedite and reduce cost, the construction of pipeline systems are proposed to use the existing easements for oil and natural gas pipelines and depending, some legal expense will be required to arrange this. Most if not all pumping stations will be constructed on government-owned property and be more readily available for pump installation, fewer may need to occupy privately owned land and these would require legal expense and some investment of time to secure before construction begins. There are many pumping systems privately manufactured that could be purchased and installed.

Energy Use and Carbon and Brine Pollution

While providing invaluable contributions to the availability of potable water through this project, desalination plants also bring with them ecological issues that need to be mitigated and addressed as part of an ecological-minded system. To address these issues, a research board will be created to constantly study improvements on reducing pollution and energy use, collaborating with administrators on incorporating them as swiftly and practically as possible.

The primary area of concern is that desalination plants contribute to carbon pollution through their robust use of energy in the desalination process. To address this issue at the outset, desalination systems shall be required to create and integrate green energy sources that shall provide a minimum of 25% of their power requirements at startup and endeavor to increase that percentage with targets as time goes by. There are developing technologies in membrane filtering, such as graphene that show promise in greatly reducing energy demands and maintenance costs for desalination. The research board shall stay up-to-date on the latest information and developments on both green energy generation and water filtering and submit recommendations as warranted on implementing these technologies to continue reducing energy consumption and related pollution.

The other major area of pollution connected to desalination plants is the production of brine as a byproduct. Brine is condensed seawater with high salinity and a concentration of contaminates found in seawater. While many desalination plants around the world simply dump untreated brine back into the ocean, which can lead to a polluting effect, NWMA desalination plants shall be required to treat brine and reduce its contaminative properties before disposing of it. Just as with the desalination process, there is a lot of development underway on treatments for brine that include the use of membranes, crystallization, solvent extraction, and even a processing to turn brine into a mineralogical resource. It is critical that the NWMA research board remains fully informed on the cutting edge of developments in the area of brine treatment and acts without hesitation to implement improvements.

VI. CONCLUSION

The damage that Climate Change wreaks on the United States is massive and increasing exponentially. In the next decade, the cost to the country will be greater than the past four decades combined. Inaction will be vastly more expensive to the U.S. than strategically investing as soon as possible in mitigating current and future harm from Climate Change. Creating a National Water Management program will help protect millions of Americans by mitigating floods, processing and delivering potable water to Americans in need and in areas suffering drought, creating a national reserve of water at a time when potable water supplies have been lessening in availability in the U.S., strengthening our national security and generating thousands of good-paying jobs in a period of economic fragility. The more frugal and constructive alternative to paying hugely rising costs year after year to repair disasters caused or intensified by Climate Change is investing in reducing the severity and expense of that damage in the first place. It is also the better moral alternative to a system of responding to the suffering of Americans only after their lives, jobs and homes have been devastated. The choice is as simple as it is stark for the country, investing in protecting the country from far more expensive and devastating events that are inevitable fulfills the duty and purpose of the federal government of the United States.

ADDITIONAL REFERENCE MATERIAL

The Washington Post
Democracy Dies in Darkness

Climate change could cost the U.S. up to 10.5 percent of its GDP by 2100, study finds

Extreme weather events will be a major source of future losses.

By Andrew Freedman
August 19, 2019 at 10:00 a.m. PDT

Extreme weather events, cuts to worker productivity and other effects of climate change could cause major global economic losses unless greenhouse gas emissions are significantly curtailed in the next few decades, according to a new working paper published Monday. The paper is the latest in a string of reports from the United Nations and global financial institutions and others showing that climate change constitutes a looming financial risk.

At a time when there's concern about a global economic downturn, the new study, circulated as a working paper in the National Bureau of Economic Research, warns of a far bigger cut to economic growth if global warming goes unchecked.

The study is unique in that it finds higher potential costs from climate change, particularly in the industrial world, compared with past research. For example, the study found that continued temperature increases of about 0.072 degrees per year (0.04 Celsius) under a roughly "business as usual," or high-emissions, scenario would yield a 7.2 percent cut to GDP per capita worldwide by 2100. (This is relative to a world in which countries see temperature increases equal to their 1960 to 2014 rate of change.)

In contrast, if countries were to cut greenhouse gas emissions in line with the Paris climate agreement, then such effects could be limited to closer to a 1.1 percent loss in GDP per capita.

"What our study suggests is that climate change is costly for all countries under the business as usual scenario (no matter whether they are hot or cold, rich or poor), and the United States will be one of the countries that will suffer the most (reflecting sharp increases in U.S. average temperatures by 2100)," study co-author Kamiar Mohaddes, an economist at the University of Cambridge, said via email.

For the United States, the study finds that if emissions of greenhouse gases are not significantly cut in keeping with the goals of the Paris accord, the country could see a 10.5 percent cut in real income by 2100. The hardest hit countries will be poorer, tropical nations, but in contrast to previous studies, the new paper finds that no country will be spared and none will see a net benefit economically from global warming.

The team of researchers from the University of Cambridge, the International Monetary Fund, the University of Southern California and the National Tsing Hua University in Taiwan examined economic data from 174 countries during the period from 1964 to 2014, and concluded that per capita economic output growth is adversely affected by prolonged changes in temperature, both above or below its historical norms. Extreme temperature and precipitation events can reverberate throughout state, national and international economies, the study found.

Increasing humidity, driven in part by climate change, is making even modest heat waves unbearable

“It is not only the level of temperature that affects economic activity, but also its persistent above-norm changes. For example, while the level of temperature in Canada is low, the country is warming up twice as fast as rest of the world and therefore is affected by climate change (including from damage to its physical infrastructure, coastal and northern communities, human health and wellness, ecosystems and fisheries),” Mohaddes said.

Other countries will experience major losses, too, if emissions of planet-warming greenhouse gases are not reduced soon. Canada, for example, could lose more than 13 percent of its GDP by 2100, while Japan, India and New Zealand could be subjected to a 10 percent hit as well.

Mohaddes said the study takes into account the changes in average temperatures and precipitation, and in the variability of weather patterns as the climate warms.

For the United States, the new study comes up with a similar damage figure as a paper cited in the National Climate Assessment, which the Trump administration released late last year. That report contained a statistic that received widespread media attention, finding that climate change could cost the country 10 percent of its GDP.

However, the previous figure was based on a 2017 paper in the journal Science, and used an extreme, although possible, climate change scenario, with about 14.4 degrees (8 Celsius) of warming by 2100 compared to preindustrial levels, which is not considered the most likely outcome.

The study released Monday comes to nearly the same figure using a more realistic global warming scenario, one that’s closer to 7.2 degrees (4 Celsius) of warming by 2100 compared to preindustrial levels.

Mohaddes says that economic losses from climate change depend in part on extreme events, which can cause temperatures to temporarily greatly exceed or fall below their historical baseline.

“The UK recently had its hottest day on record. Train tracks buckled, roads melted, and thousands were stranded because it was out of the norm. Such events take an economic toll, and will only become more frequent and severe without policies to address the threats of climate change,” Mohaddes said in a statement.

The study, like other projections on how climate change may influence economic growth, makes assumptions about emissions trends, how society may try to adapt to the effects of global warming and other factors. However, although the specific figures may contain uncertainties, the overarching finding that all countries will experience economic damage from climate change, rather than just poor, tropical nations, is more robust.

NATIONAL GEOGRAPHIC

nationalgeographic.com

Why is America running out of water?

By Jon Heggie

PUBLISHED August 12, 2020

In March 2019, storm clouds rolled across Oklahoma; rain swept down the gutters of New York; hail pummeled northern Florida; floodwaters forced evacuations in Missouri; and a blizzard brought travel to a stop in South Dakota. Across much of America, it can be easy to assume that we have more than enough water. But that same a month, as storms battered the country, a government-backed report issued a stark warning: America is running out of water.

Within as little as 50 years, many regions of the United States could see their freshwater supply reduced by as much as a third, warn scientists. Of all the freshwater basins that channel rain and snow into the rivers from which we draw the water we rely on for everything from drinking and cooking to washing and cleaning, nearly half may be unable to meet consumers' monthly demands by 2071. This will mean serious water shortages for Americans.

Shortages won't affect only the regions we'd expect to be dry: with as many as 96 out of 204 basins in trouble, water shortages would impact most of the U.S., including the central and southern Great Plains, the Southwest, and central Rocky Mountain states, as well as parts of California, the South, and the Midwest. And if 50 years seems like a long way off, the reality is much sooner: shortages could occur in 83 basins as early as 2021. With 40 out of 50 states expecting water shortages, it's time to start thinking about where our water is going.

From the snow-capped Rockies to the flat expanses of the prairies, and from the wetlands of Florida to the deserts of Arizona, the U.S. is a country of geographical extremes with rainfall patterns to match: Louisiana gets over 60 inches of rainfall a year, while in Nevada, less than 10 inches of rain falls annually in valleys and deserts. But climate change is impacting precipitation. In broad terms, while the wettest regions of the U.S. are getting wetter, the drier areas are getting drier, and there are some seasonal shifts in water patterns—rising temperatures mean the snowmelt that feeds many rivers begins and ends earlier, contributing to summer water shortages. Even where precipitation is projected to increase, mostly in the nation's northern regions, the trend is toward more intense concentrations of rainfall that are difficult to capture and use. At the same time, 145 basins are expected to be drier, especially in the Southwest, southern Great Plains, and Florida. In the West, California has already faced some of its worst droughts in recorded history.

Along with decreasing rainfall comes rising temperatures. By 2050 the U.S. could be as much as 5.7°F warmer, and extreme weather events, such as heatwaves and drought, could be more intense and occur more frequently. As temperatures warm, evaporation increases, further decreasing water in lakes, reservoirs, and rivers. For example, every degree of warming in the Salt Lake City region could drop the annual water flow of surrounding streams by as much as 6.5 percent—for cities in the western U.S. that rely on cool temperatures to generate snow and rain, warmer weather is bad news.

As the U.S. water supply decreases, demand is set to increase. On average, each American uses 80 to 100 gallons of water every day, with the nation's estimated total daily usage topping 345 billion gallons—enough to sink the state of Rhode Island under a foot of water. By 2100 the U.S. population will have increased by nearly 200 million, with a total population of some 514 million people. Given that we use water for everything, the simple math is that more people mean more water stress across the country.

Natural springs like the Morrison Spring, Florida release freshwater from aquifers to feed rivers and other bodies of water. 120 million Americans rely on these ancient subterranean lakes for drinking water, but they're becoming depleted.

And we are already tapping into our reserves. Aquifers, porous rocks and sediment that store vast volumes of water underground, are being drained. Nearly 165 million Americans rely on groundwater for drinking water, farmers use it for irrigation—37 percent of our total water usage is for agriculture—and industry needs it for manufacturing. Groundwater is being pumped faster than it can be naturally replenished. The Central Valley Aquifer in California underlies one of the nation's most agriculturally productive regions, but it is in drastic decline and has lost about ten cubic miles of water in just four years.

Decreasing supply and increasing demand are creating a perfect water storm, the effects of which are already being felt. The Colorado River carved its way 1,450 miles from the Rockies to the Gulf of California for millions of years, but now no longer reaches the sea. In 2018, parts of the Rio Grande recorded their lowest water levels ever; Arizona essentially lives under permanent drought conditions; and in South Florida's freshwater aquifers are increasingly susceptible to salt water intrusion due to over-extraction.

With a potential disaster looming, there are doubts about the effectiveness and environmental impacts of traditional responses, including expanding reservoirs and mining more aquifers. New solutions are needed. Desalination plants can produce as much as 50 million gallons of freshwater a day—California has 11 desalination plants, and another 10 are being planned. But despite costs that are half of what they once were, desalinated water is still about twice as expensive as extracted freshwater. Water transfers from wet to dry regions, such as from the Colorado River basin to California, are another expensive option already in use. Proposals have periodically forwarded to pipe water south from Alaska and Canada, but costs and complexity have prevented any further planning or development.

The Atlantic Ocean is a huge source of water, but it's expensive to process to make it useable. Regardless, desalination plants are springing up across the US in response to a looming water crisis.

Perhaps the simplest solution is to use less water. Los Angeles has grown by a million people since the 1970s, but water usage is still the same. Water meters and careful pricing help discourage waste, while fixing aging infrastructure will keep more water in the system—a water mains break in the U.S. approximately every two minutes. In the agriculture sector, reducing irrigation by as little as two percent could avert shortages in one-third of the affected basins; farmers could save water by using drip irrigation, soil moisture sensors, and planting more drought-resistant crops. And every American can save more water at home in multiple ways, from taking shorter showers to not rinsing dishes under a running faucet before loading them into a dishwasher, a practice that wastes around 20 gallons of water for each load. These are such small actions, but taken by many, they could amount to the biggest water savings—and we're going to need every drop.

YaleEnvironment360
Published at the Yale School of Forestry & Environmental Studies

As Water Scarcity Increases, Desalination Plants Are on the Rise

After decades of slow progress, desalination is increasingly being used to provide drinking water around the globe. Costs for processing salt water for drinking water have dropped, but it remains an expensive option and one that creates environmental problems that must be addressed.

By Jim Robbins • June 11, 2019

Some 30 miles north of San Diego, along the Pacific Coast, sits the Claude "Bud" Lewis Carlsbad Desalination Plant, the largest effort to turn salt water into fresh water in North America.

Each day 100 million gallons of seawater are pushed through semi-permeable membranes to create 50 million gallons of water that is piped to municipal users. Carlsbad, which became fully operational in 2015, creates about 10 percent of the fresh water the 3.1 million people in the region use, at about twice the cost of the other main source of water.

Expensive, yes, but vital for the fact that it is local and reliable. "Drought is a recurring condition here in California," said Jeremy Crutchfield, water resources manager at the San Diego County Water Authority. "We just came out of a five-year drought in 2017. The plant has reduced our reliance on imported supplies, which is challenging at times here in California. So it's a component for reliability."

A second plant, similar to Carlsbad, is being built in Huntington Beach, California with the same 50-million-gallon-a-day capability. Currently there are 11 desalination plants in California, and 10 more are proposed.

The cost of desalinated water has been coming down as the technology evolves and the cost of other sources increases

It's been a long time coming for desalination — de-sal for short. For decades, we have been told it would one day turn oceans of salt water into fresh and quench the world's thirst. But progress has been slow.

That is now changing, as desalination is coming into play in many places around the world. Several factors are converging to bring new plants on line. Population has boomed in many water-stressed places, including parts of China, India, South Africa and the United States, especially in Arizona and California. In addition, drought — some of it driven by a changing climate – is occurring in many regions that not that long ago thought their supplies were ample.

San Diego is one of those places. With just 12 inches of rain a year in the Mediterranean climate of Southern California and no groundwater, the region gets half of its water from the distant Colorado River. The amount of snow that falls in the Rocky Mountains and keeps that mighty river flowing, however, has greatly diminished over the last two decades and according to some researchers may be part of a permanent aridification of the West. Climate change is a very real phenomenon for water managers throughout the Southwest and elsewhere.

Desalination has been growing steadily in the last decade. Jones et al, Science of the Total Environment, 2019

Meanwhile, the cost of desalinated water has been coming down as the technology evolves and the cost of other sources increases. In the last three decades, the cost of desalination has dropped by more than half.

A boom in de-sal, though, doesn't mean that everywhere with access to the sea has found a new source of fresh water. Circumstances play a large role. "As populations increase and existing surface water supplies are being tapped out or groundwater is depleted or polluted, then the problems are acute and there are choices to be made" about de-sal, said Michael Kiparsky of the Wheeler Water Institute at the University of California, Berkeley School of Law. "There are places around the world where de-sal makes economic sense, where there is high pressure on the water resources plus a lot of available energy resources," such as the Middle East.

De-sal proponents acknowledge the industry must confront and solve some serious environmental issues if it is to continue to grow. Desalination requires vast amounts of energy, which in some places is currently provided by fossil fuels. Kiparsky warns of a feedback loop where more de-sal is needed as the planet warms, which leads to more greenhouse gas emissions. In addition, there are serious concerns about the damage to marine life from the plant's intake systems and extra-salty wastewater.

Globally, more than 300 million people now get their water from desalination plants, from the U.S. Southwest to China.

The first large-scale de-sal plants were built in the 1960s, and there are now some 20,000 facilities globally that turn sea water into fresh. The kingdom of Saudi Arabia, with very little fresh water and cheap energy costs for the fossil fuels it uses in its de-sal plants, produces the most fresh water of any nation, a fifth of the world's total.

Australia and Israel are also major players. When the Millennium Drought gripped southeastern Australia from the late 1990s until 2009 water systems in the region dropped to small fractions of their storage capacity. Facing a crisis, Perth, Melbourne, and other cities embarked on a large desalination plant spree. The plant in Melbourne, which provided its first water in 2017, cost $3.5 billion to build and provides a third of the city's supply. It's critical because the region has had below-average rainfall for 18 of the last 20 years.

Israel, too, is all in on desalination. It has five large plants in operation, and plans for five more. Chronic water shortages there are now a thing of the past, as more than half of the country's domestic needs are met with water from the Mediterranean.

Globally, more than 300 million people now get their water from de-salination plants, according to the International Desalination Association.

But despite the need, de-sal plants will not be built on every coastline. Foremost among the barriers is the cost of constructing a plant and the cost of processing the water. The San Diego County Water Authority pays about $1,200 for an acre-foot of water sourced from the Colorado River and the Sacramento San Joaquin River Delta and pumped hundreds of miles to Southern California. The same amount from the Carlsbad plant — enough to supply a family of five for a year — costs about $2,200. As Lake Mead — the reservoir of Colorado River water on the Nevada-Arizona border that supplies San Diego — drops precipitously, it may someday, perhaps in the next several years, no longer be able to supply San Diego. Certainty is paramount.

De-sal, however, is plagued by some serious environmental problems. There are two types of desalination – thermal, which heats up water and then captures the condensation, and reverse osmosis, which forces sea water through the pores of a membrane that are many times smaller than the diameter of a human hair. This traps salt molecules, but allows the smaller water molecules to go through. Both require a great deal of energy, and greenhouse gas emissions created by the power needed – especially in the Middle East, where fossil fuels generate electricity – are a significant contributor to global warming.

There are ecological impacts as well. It takes two gallons of sea water to make a gallon of fresh water, which means the gallon left behind is briny. It is disposed of by returning it to the ocean and – if not done properly by diffusing it over large areas – can deplete the ocean of oxygen and have negative impacts on sea life.

A recent study found that the problem of brine waste from the desalination process has been underestimated by 50 percent.

A study by the UN Institute for Water, Environment and Health published earlier this year contends that the problem of brine waste has been underestimated by 50 percent and that, when mixed with the chemicals meant to keep systems from fouling, the brine is toxic and causes serious pollution.

Another problem comes from the sucking in of sea water for processing. When a fish or other large organism gets stuck on the intake screen, it dies or is injured; in addition, fish larvae, eggs and plankton get sucked into the system and are killed.

“At our intake we [draw in] tiny little organisms, that amount to about a pound and a half of adult fish per day,” said Jessica Jones, a spokesperson for Poseidon Water, which owns the Carlsbad plant. “To mitigate that we are restoring 66 acres of wetlands in San Diego Bay. And we just got a new intake permitted which will lessen the impacts.”

The Tuas Desalination Plant in Singapore, which opened in 2018, can produce 30 million gallons of fresh water a day. Associated Press

According to Heather Cooley, research director at the Pacific Institute, “There are a lot of unknowns around the impact on sea life. There hasn’t been a lot of monitoring at the facilities.” A strategy increasingly being used to obviate, or reduce, that problem is to bury the sea water intakes beneath the sea floor and use the sandy ocean bottom as a natural filter.

In 2016, California passed the Desalination Amendment, which tightened regulations for intake and brine disposal. Proponents of desalination contend the changes have been onerous and are slowing the march toward a de-sal future.

Because of the cost of seawater processing and the impacts on the ocean, much of the recent desalination growth has involved the use of brackish water. The solids in brackish water are one-tenth the amount in ocean water, and that makes the process much cheaper.

Much of the recent desalination growth has involved using brackish water, which is cheaper to process than sea water.

Arizona, perpetually short on water and facing a Colorado River supply shortage, is looking at both a seawater de-sal plant in partnership with Mexico – which has the ocean access that the state lacks – and at plants that can treat the 600 million acre-feet of brackish water deposits the state estimates it has.

Texas, meanwhile, now has 49 municipal desal plants that process brackish water, both surface and subsurface. San Antonio currently is building what will be the largest brackish water desal plant in the country. In its first phase, it produces 12 million gallons a day, enough for 40,000 families, but by 2026, the plant – known as H2Oaks – will produce 30 million gallons a day. Brackish water de-sal costs $1,000 to $2,000 per acre-foot.

The Pacific Institute's Cooley argues that before building de-sal plants, municipalities should fully implement conservation programs, promote potable re-use – the re-use of wastewater, also known as toilet-to-tap recycling – or treat storm water runoff. "It makes sense to do the cheaper options first and leave the more expensive options down the road to be developed when you need them," she said.

MIT News
ON CAMPUS AND AROUND THE WORLD

Desalination gets a graphene boost

Jeffrey Grossman applies new materials research to making desalination cheaper and more efficient.

Eric Brown | MIT Industrial Liaison Program
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With the intensifying drought in California, the state has accelerated the construction of desalination plants. Yet due to high construction and operating costs, as well as environmental concerns, we're not likely to see reclaimed seawater represent more than a small fraction of America's clean water reserves for some time to come. Aside from other costs, the immense amounts of energy required to make clean water from seawater continues to make desalination a niche solution in most parts of the world.

When Jeffrey Grossman, a professor at MIT's Department of Materials Science and Engineering (DMSE), began looking into whether new materials might reduce the cost of desalination, he was surprised to find how little research and development money was being applied to the problem.

"A billion people around the world lack regular access to clean water, and that's expected to more than double in the next 25 years," Grossman says. "Desalinated water costs five to 10 times more than regular municipal water, yet we're not investing nearly enough money into research. If we don't have clean energy we're in serious trouble, but if we don't have water we die."

At the Grossman Group, which explores the development of new materials to address clean energy and water problems, a possible solution may be at hand. Grossman's lab has demonstrated strong results showing that new filters made from graphene could greatly improve the energy efficiency of desalination plants while potentially reducing other costs as well.

Graphene, which results from slicing off an atom-thick layer of graphite, is increasingly emerging as something of a wonder material. The Grossman Group, for example, is also looking into using it as a cheaper alternative to silicon for making solar cells.

"It's never been a more exciting time to be a materials scientist," says Grossman. "When you look at clean tech or water filtration, you find that the energy conversion bottleneck stems from the material. We can now design materials pretty much all the way down to the scale of the atom in almost any way we want, tailoring materials in ways that were previously impossible. There's a convergence emerging in which we are facing enormously pressing problems that can only be solved by developing new materials."

Graphene filters: Up to 50 percent less energy

First isolated in 2003, graphene has different electrical, optical, and mechanical properties than graphite. "It's stronger than steel, and it has unique sieving properties," Grossman says. At only an atom thick, there's far less friction loss when you push seawater through a perforated graphene filter compared with the polyamide plastic filters that have been used for the last 50 years, he says.

“We have shown that perforated graphene filters can handle the water pressures of desalination plants while offering hundreds of times better permeability,” Grossman explains. “The process of pumping seawater through filters represents about half the operating costs of a desalination plant. With graphene, we could use 15 percent less energy for seawater and up to 50 percent less energy for brackish water.”

Another advantage is that graphene filters don’t become fouled with bio-growth at nearly the rate that occurs with polyamide filters. Desalination plants often run at reduced efficiency due to the need to frequently clean the filters. In addition, the chlorine used to clean the filters reduces the structural integrity of the polyamide, requiring frequent replacement. By comparison, graphene is resistant to the damaging effects of chlorine.

According to Grossman, you could easily replace polyamide filters with graphene filters in existing plants. Like polyamide filters, graphene filters can be mounted on robust polysulfone supports, which have larger holes that sieve out particulates.

Yet, significant challenges remain in bringing down costs. The Grossman Group has made good progress in creating high volumes of graphene at a reasonably low cost. A more serious challenge, however, is cost-effectively poking uniform holes in the graphene in a highly scalable manner.

“A typical plant has tens of thousands of membranes, configured in two-meter long tubes, each of which has 40 square meters of rolled up active membrane,” Grossman says. “We have to match that volume at the same cost, or it’s a nonstarter.”

Making graphene on the cheap

The traditional way to make graphene — since its first isolation in 2003, mind you — is to peel it off with adhesive. “You literally take a piece of Scotch Tape to graphite and you peel,” Grossman explains. “If you keep doing this, you eventually wind up with a single layer. The problem is it would take forever to peel off enough graphene for a desalination plant.”

Another approach is to “grow” graphene by applying super-hot gases to copper foil. “Growing graphene provides the best quality, which is why the semiconductor industry is interested in it,” Grossman says. The process, however, is very expensive and energy-intensive.

Instead, the Grossman Group is using a much more affordable chemical approach, which produces sufficient quality for creating desalination membranes. “Fortunately, our application doesn’t require the best quality,” says Grossman. “With the chemical technique, we put graphite in a solution, and apply low temperature chemistry to break apart the entire chunk of graphite into sheets. We can get lots of graphene very cheaply and quickly.”

Creating pores that block salt but let water molecules pass is a steeper challenge. The reason desalination is possible in the first place is that when diffused in water, salt ions bond with water molecules, thereby creating a larger entity. But the difference in size compared to a free water molecule is still frustratingly small.

"The challenge is to find the sweet spot of about 0.8 nanometers," Grossman says. "If your pores are at 1.5 nm, then both the water and salt will pass through. If they're half a nanometer, then nothing gets through."

A 0.8 nm hole is "smaller than we've ever been able to make in a controllable way with any other material," Grossman says. "And we need to do this over a very large area very consistently and cheaply."

The Grossman Group is pursuing three techniques to make nanoporous graphene membranes, all of which use chemical and thermal energy rather than mechanical processes. "If you tried to use lithography, it would take years," Grossman says. "Our first approach involves making the holes too big, and then carefully filling them in. Another tries to make them exactly the right size, and the third involves starting with a material without holes and then carefully ripping it apart."

The chemical technique for making graphene actually produces graphene oxide, which is considered undesirable for semiconductors, but is fine for filters. As a result, the researchers were able to avoid the difficult step of removing the oxygen from the graphene oxide. In fact, they found a way to use the oxygen to their advantage.

"By controlling the way the oxygen is bonded to the graphene sheet, we can use chemical and thermal energy to drill the holes with the help of the oxygen," Grossman says.

First target: Brackish water

As the Grossman Group continues to work on the challenge of manufacturing and perforating graphene sheets, Grossman is looking to leverage other benefits of graphene filters to help bring the technology to market.

Although graphene should improve efficiency with seawater and the even saltier, dirtier water used in hydraulic fracturing, it will likely debut in plants that clean brackish water, such as found in estuaries. "It turns out that higher permeability even by a factor of two or three would make a bigger difference with brackish water than with seawater," Grossman says. "You lower the energy consumption in both cases, but more so for brackish water."

Graphene filters could also enable the construction of smaller, cheaper plants. "With graphene you have more choices in how you operate the plant," Grossman says. "You could apply the same pressures but get more water out, or you could operate it at lower pressures and get the same amount of water, but at a lower energy cost."

Grossman notes that it can take years or even decades to site and permit a plant in heavily populated coastal areas. "A lot of effort goes into how you're going to build the plant and where you're going to find enough land," Grossman says. "Having the option to build a smaller plant would be a big advantage."

MIT News
ON CAMPUS AND AROUND THE WORLD

Turning desalination waste into a useful resource

Process developed at MIT could turn concentrated brine into useful chemicals, making desalination more efficient.

David L. Chandler | MIT News Office
Publication Date: February 13, 2019

The rapidly growing desalination industry produces water for drinking and for agriculture in the world's arid coastal regions. But it leaves behind as a waste product a lot of highly concentrated brine, which is usually disposed of by dumping it back into the sea, a process that requires costly pumping systems and that must be managed carefully to prevent damage to marine ecosystems. Now, engineers at MIT say they have found a better way.

In a new study, they show that through a fairly simple process the waste material can be converted into useful chemicals — including ones that can make the desalination process itself more efficient.

The approach can be used to produce sodium hydroxide, among other products. Otherwise known as caustic soda, sodium hydroxide can be used to pretreat seawater going into the desalination plant. This changes the acidity of the water, which helps to prevent fouling of the membranes used to filter out the salty water — a major cause of interruptions and failures in typical reverse osmosis desalination plants.

The concept is described today in the journal *Nature Catalysis* and in two other papers by MIT research scientist Amit Kumar, professor of mechanical engineering John. H. Lienhard V, and several others. Lienhard is the Jameel Professor of Water and Food and the director of the Abdul Latif Jameel Water and Food Systems Lab.

"The desalination industry itself uses quite a lot of it," Kumar says of sodium hydroxide. "They're buying it, spending money on it. So if you can make it in situ at the plant, that could be a big advantage." The amount needed in the plants themselves is far less than the total that could be produced from the brine, so there is also potential for it to be a saleable product.

Sodium hydroxide is not the only product that can be made from the waste brine: Another important chemical used by desalination plants and many other industrial processes is hydrochloric acid, which can also easily be made on site from the waste brine using established chemical processing methods. The chemical can be used for cleaning parts of the desalination plant, but is also widely used in chemical production and as a source of hydrogen.

Currently, the world produces more than 100 billion liters (about 27 billion gallons) a day of water from desalination, which leaves a similar volume of concentrated brine. Much of that is pumped back out to sea, and current regulations require costly outfall systems to ensure adequate dilution of the salts. Converting the brine can thus be both economically and ecologically beneficial, especially as desalination continues to grow rapidly around the world. “Environmentally safe discharge of brine is manageable with current technology, but it’s much better to recover resources from the brine and reduce the amount of brine released,” Lienhard says.

The method of converting the brine into useful products uses well-known and standard chemical processes, including initial nanofiltration to remove undesirable compounds, followed by one or more electrodialysis stages to produce the desired end product. While the processes being suggested are not new, the researchers have analyzed the potential for production of useful chemicals from brine and proposed a specific combination of products and chemical processes that could be turned into commercial operations to enhance the economic viability of the desalination process, while diminishing its environmental impact.

“This very concentrated brine has to be handled carefully to protect life in the ocean, and it’s a resource waste, and it costs energy to pump it back out to sea,” so turning it into a useful commodity is a win-win, Kumar says. And sodium hydroxide is such a ubiquitous chemical that “every lab at MIT has some,” he says, so finding markets for it should not be difficult.

The researchers have discussed the concept with companies that may be interested in the next step of building a prototype plant to help work out the real-world economics of the process. “One big challenge is cost — both electricity cost and equipment cost,” at this stage, Kumar says.

The team also continues to look at the possibility of extracting other, lower-concentration materials from the brine stream, he says, including various metals and other chemicals, which could make the brine processing an even more economically viable undertaking.

“One aspect that was mentioned … and strongly resonated with me was the proposal for such technologies to support more ‘localized’ or ‘decentralized’ production of these chemicals at the point-of-use,” says Jurg Keller, a professor of water management at the University of Queensland in Australia, who was not involved in this work. “This could have some major energy and cost benefits, since the up-concentration and transport of these chemicals often adds more cost and even higher energy demand than the actual production of these at the concentrations that are typically used.”

The New York Times

nytimes.com

Tokyo Is Preparing for Floods 'Beyond Anything We've Seen'

By Hiroko Tabuchi

Oct. 6, 2017

KASUKABE, Japan — The cavernous underground cisterns here north of Tokyo could hold the Statue of Liberty, a scale that underscores the site's immense task: protecting the world's most populous metropolis from flooding.

Linked by tunnels that divert water away from the region's most vulnerable floodplains, the $2 billion underground anti-flood system, completed in 2006, is an extraordinary example of the defenses that global cities are readying as they face an era of extreme weather brought on by climate change.

In the United States, towns and cities battered by a string of devastating hurricanes are just starting to come to terms with what it could take to bolster their storm protections. Houston city officials have pleaded for state and federal funds to help build a new $400 million reservoir that could keep storm water from inundating downstream neighborhoods.

"We're preparing for flooding beyond anything we've seen," said Kuniharu Abe, who heads up the underground site. "Until now, at least, we've been successful."

But even in Tokyo, the onset of more frequent and intense storms has forced officials to question whether the region's protections are strong enough, a concern that has become more urgent as the city prepares to host the 2020 Olympic Games.

Across Japan, rainfall measuring more than two inches an hour has increased by 30 percent over the past three decades, the Japan Meteorological Agency estimates. The frequency of rainfall of over three inches an hour has jumped 70 percent. The agency attributes the increase of these intense rains to global warming, heralding a new era in a country that is already among the world's wettest, with a language that has dozens of words for rain.

Rising oceans also make the Tokyo metropolitan region, home to 38 million people, vulnerable to storm surges, even as major redevelopment projects open up the previously industrial waterfront to new residences and businesses. And years of pumping groundwater has led some parts of the city to sink by almost 15 feet over the past century. Wide areas of Tokyo now sit below sea level, protected by aging dikes.

Extreme rainfall, along with the potential for destructive earthquakes and tsunamis, make Tokyo and the neighboring port city of Yokohama the riskiest metropolitan area in the world, according to a 2014 study of natural disaster risks by the Swiss Re reinsurance firm.

In late 2015, heavy typhoon rains wreaked havoc across greater Tokyo, forcing a record 670 million cubic feet of water into the underground facility, known as the Metropolitan Area Outer Underground Discharge Channel. It took four days for the site's four large pumps — powered by engines similar to those used in a Boeing 737 jet — to clear the deluge.

"Tokyo faces dangers on all sides," said Nobuyuki Tsuchiya, an anti-flooding expert and the former head of civil engineering for Tokyo's flood-prone Edogawa ward. "It's difficult to say that it's doing enough."

A big challenge lies in Japan's deteriorating government finances.

Work began on the facility here in Kasukabe in the early 1990s, at a time when Japan was pouring funds, and concrete, into huge public works projects. But now, with a government debt more than twice the size of its economy and spiraling costs of caring for an aging population, the country is less able to muster the resources to fund such ambitious projects.

Even Mr. Abe, who runs the Kasukabe site, acknowledges that the sprawling operation may have been a one-time feat. And the visitors he gets from developing countries interested in learning about the site, he said, often raise their eyebrows when they learn of the construction costs.

"I'm not sure Japan can build something like this again," Mr. Abe said.

Experts have also questioned the wisdom of erecting more concrete defenses in a country that has already dammed most of its major river systems and fortified entire shorelines with breakwaters and concrete blocks. Some of these protections, they say, only encourage development in regions that could still be vulnerable to future flooding.

In eastern Saitama, where the Kasukabe facility has done the most to reduce floods, local industry has flourished; the region has successfully attracted several large e-commerce distribution centers and a new shopping mall.

"There's a limit to what you can do with hardware, and it leads to a false sense of security," said Toshitaka Katada, a professor in disaster prevention at the University of Tokyo. Investment in infrastructure needed to be paired with more public education in disaster survival skills, like familiarity with local flood hazard maps or evacuation protocols, he said.

(Here, Prof. Katada has a convincing track record. A program he led in the coastal city of Kamaishi that drilled schoolchildren to run to higher ground in the event of a tsunami is credited with saving some 3,000 lives when 50-foot tsunami waves struck the city in 2011.)

Still, the Kasukabe operation remains a critical part of Tokyo’s defenses, say officials at Japan’s Land Ministry, which runs the site. Five vertical, underground cisterns, almost 250 feet deep, take in storm water from four rivers north of Tokyo.

A series of tunnels connect the cisterns to a vast tank, larger than a soccer field, with ceilings held up by 60-foot pillars that give the space a temple-like feel. From that tank, industrial pumps discharge the floodwater at a controlled pace into the Edo river, a larger river system that flushes the water into Tokyo Bay.

Between floods, site managers run tours of the facility, inviting members of the public to walk on the floor of the vast tank and to peer into the murky cisterns.

“This is another important role,” said Mr. Abe’s deputy, Yasuyuki Osa, after a recent tour, “to get people to think about the danger of floods, and how we can adapt.”