WATER LOG

A Legal Reporter of the Mississippi-Alabama Sea Grant Consortium

Volume 42, Number 3 September 2022

Greenhouse Gas Emissions

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StormCon and WaterPro Joint Conference

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National Harbor, MD

https://bit.ly/stormconwaterpro

Gulf Coast Energy Forum

Oct. 12-14, 2022
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https://www.gulfcoastenergyforum.com

2022 Gulf Coast Chapter Annual Meeting, Western Dredging Association

Nov. 7-9, 2022
New Orleans, LA

https://bit.ly/gccam22

North American Invasive Species Management Association Annual Conference

Nov. 7-10, 2022
Sanibel Island, FL

https://bit.ly/naisma

Greenhouse Gases 101

Kristina Alexander

Credit: Gerald Simmons

Arguments over greenhouse gas emissions show up in published court opinions beginning in 1990 and continue to the present, including a Supreme Court case issued June 30, 2022. This article gives a summary overview of the regulation of greenhouse gases in the United States and encourages the exploration of the issue in depth from the myriad reputable sources.

Initial Greenhouse Gas Legislation

In 1978 the U.S. Congress enacted the "National Climate Program Act," in part because Congress found "an ability to anticipate natural and man-induced changes in climate would contribute to the soundness of policy decision."[1] The act directed studies and agency attention, and set up 5-year program to assess "the effect of climate on the natural environment, agricultural production, energy supply and demand, [and] land and water resources" among other things. While Congress was concerned about changes in the climate, greenhouse gases were not mentioned.

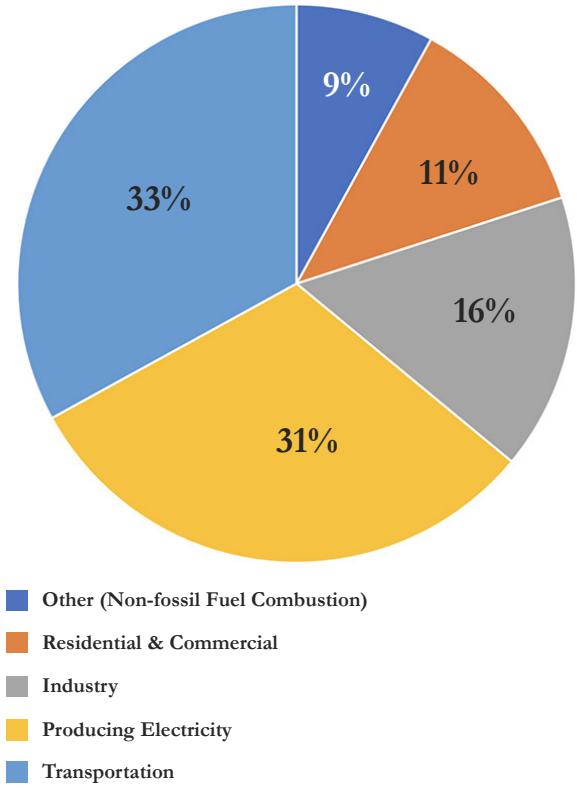
A search of a database of U.S. statutes found the term *greenhouse gas* was first used in U.S. public laws in 1987 in a State Department appropriations act finding U.S. policy should seek to "increase worldwide understanding of the greenhouse effect and its environmental and health consequences" which would include "slowing the rate of increase of concentrations of greenhouse gases in the atmosphere in the near term; and stabilizing or reducing atmospheric concentrations of greenhouse gases over the long term."[2]

What Gases Are Greenhouse Gases?

While many gases are identified as Greenhouse Gases (GHGs), the most important ones are: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). These gases are emitted by natural and manmade sources, albeit not in equal quantities. Some artificially-developed gases, or synthetic gases, also are identified as GHGs. These include fluorinated gases (F-gases) such as hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride.[3] Also, synthetic gases identified as Ozone-Depleting Substances (ODS), such as chlorofluorocarbons (CFCs) which were common in aerosols, also act as greenhouse gases.[4]

When ODS were banned in the late 1980s, fluorinated gases frequently took their place in products. While F-gases have not been found to deplete the ozone layer, they still act as greenhouse gases. According to the Environmental Protection Agency (EPA), the federal agency with the primary role in regulating GHGs in the United States, in 2009, six gases, including three F-gases, when combined are "the root cause of human-induced climate change," and it identified these six as "well-mixed greenhouse gases."[5]

2020 U.S. Carbon Dioxide Emissions, By Source



How Did They Get the Name?

They are called greenhouse gases because once released into the atmosphere they act to insulate the earth. Instead of infrared energy escaping from earth into space, it is absorbed by GHGs, leading to a phenomenon first known as *global warming*, but now more generally termed *climate change*.[6]

The impact of a GHG varies. According to the European Union's European Environment Agency, F-gases can have a greenhouse effect up to 23,000 times more powerful than the same amount of CO_2. However, F-gases are emitted in far smaller quantities than is CO_2. One reason GHGs have different impacts is that GHGs stay in the atmosphere for different durations – from 10 years to 1,000s of years depending on the gas.

The method scientists use to compare how much of a threat each GHG poses is known as the Global Warming Potential (GWP). One court described the GWP as "the tool preferred by leading scientists for analyzing the effects of greenhouse gases."[7] That method uses carbon dioxide – the biggest player among GHGs – as a baseline for the comparison. According to the EPA, carbon dioxide makes up to 79% of GHGs emitted from human activities. The EPA describes the GWP as "a measure of how much energy the emissions of 1 ton of a gas will absorb over a given period of time, relative to the emissions of 1 ton of carbon dioxide."[8] That given period of time is 100 years. For example, methane over 100 years has a GWP of between 27 and 30, according to the EPA. According to other sources, methane's GWP is 34 which means a ton of methane during 100 years "trap[s] 34 times more heat than 1 [ton] of CO_2."[9] The GWP for nitrous oxide (yes, that is laughing gas) is 273, according to the EPA, and the agency says that F-gases and ODS can have GWPs in the "thousands or tens of thousands."

Laws About GHGs

In 1990, Congress amended the Clean Air Act to address the problem of ODSs, but was silent on GHGs.[10] In 1992, Congress directed the Secretary of the Department of Energy to produce a report comparing "alternative policy mechanisms for reducing the generation of greenhouse gases" including caps on GHG generation and "federal standards for energy efficiency for major sources of greenhouse gases, including … power plants, industrial processes, automobile fuel economy, appliances, and buildings, and for emissions of methane."[11]

Thus, GHGs eventually were recognized by Congress which used its authority to set objectives such as in the Biomass Research and Development Act of 2000, which had a goal of converting biomass into biofuel to offer "near-zero net greenhouse gas emissions."[12] However, Congress did not set emission limits on GHGs, despite the unanimous ratification by Senate in 1992 of the international treaty signed by President George H.W. Bush committing to reduce GHGs.[13]

Science and the Courts

Just as Congress has not directly required GHG reduction, the regulatory path for controlling GHGs is not a straight line. Consider, for example, the story of hydrofluorocarbons, an F-gas. Hydrofluorocarbons were developed to replace CFCs because they did not damage the ozone layer. The EPA put them on a regulatory list of safe substitutes for CFCs in 1994. However, hydrofluorocarbons were found to have such high GWPs that in 2015 the EPA placed them on the list of ozone depleting substances, identifying them as unsafe substances. This change did not go over well with manufacturers of hydrofluorocarbons, who sued. The manufacturers succeeded in getting a federal judge (now-Supreme Court Justice Brett Kavanagh) to reject that the EPA had the authority to make manufacturers replace those gases with safer gases.[14] However, then-Judge Kavanagh upheld the EPA decision to place hydrofluorocarbons on the list of ODS.

GHGs eventually all mix together in the atmosphere, regardless of whether the source is cow or coal-fired power plant. When it comes to CO_2, the EPA says the primary source of that pollutant is transportation, which accounts for 33% of all CO_2 emissions. Close second is electricity production, which accounts for 31%. A general category the EPA describes as "industry" contributes 16%, and the remaining emissions arise from residential and commercial (11%) and other (9%). It is a complicated mix. (See chart, p. 4.)

The fact that GHGs are ubiquitous has proved troublesome for plaintiffs seeking to limit GHG emissions. In order to bring a claim before a court, a plaintiff must be able to establish "standing," which generally speaking, means showing there is an actual or imminent injury, that the injury is traceable to the defendant, and that the court case could fix the injury. This can be difficult when alleging that specific emissions from a specific source caused a specific injury to the plaintiff when those gases are known as "well-mixed" and the harm is to the entire world. But the link to injury is an important legal standard. As put by one judge, a causal link between the injury and the ability of a court to fix the injury is necessary when asserting harm from GHGs, otherwise lawsuits could come from "anyone with the wit to shout 'global warming' in a crowded courthouse."[15]

In that case from 1990, the plaintiffs argued that in order to avoid catastrophic injury to the planet automobile fuel efficiency requirements should be set higher. The divided court, which included future Supreme Court Justice Ruth Bader Ginsburg, disputed whether harm to the world amounted to standing. While the Notorious RBG and one other judge found standing existed for the environmental plaintiff, a dissenting judge expressed problems finding that slightly less fuel efficient cars – 26.5 mpg rather than 27.5 mpg – could be linked to the injury: "the increase in greenhouse gases that the … decision can be expected to generate is so small a contribution to the quantum necessary to produce the projected catastrophe."[16]

Almost 20 years later in 2007, the Supreme Court, on which Justice Ginsberg now sat, held the Commonwealth of Massachusetts had standing to bring climate change claims against the EPA, based on the agency's refusal to regulate vehicle emissions; the fact that the harms were widely shared did not diminish the injury to Massachusetts.[17] In that case, the EPA was sued for denying a petition to restrict vehicular emissions, finding no specific congressional mandate directing the agency to regulate GHGs, as compared to the one for ODSs.[18] The Court held that the EPA should not have denied the petition: the Clean Air Act allowed the EPA to regulate fuel rates for new vehicles if it found that emissions contributed to climate change.

However, the Supreme Court has not found that the EPA may use the Clean Air Act in every situation to restrict GHG releases. For example, the EPA tried to use the act to require permits for stationary sources (i.e. not vehicles) based solely on GHG emissions. In 2014 the Supreme Court found that the Clean Air Act did not stretch to add permittees under that circumstance.[19] However, the Court did approve EPA-required best practices to limit the production of GHGs by sources for which the Clean Air Act already required permits.

On June 30, 2022, the Supreme Court refined that position in *West Virginia v. EPA*. That case challenged an


Credit: Eric Schmuttenmaer

EPA program designed to achieve the "best system of emission reduction" of GHGs from power plants in part by shifting power production away from coal-fired power plants. EPA set GHG limits that the Court described as being so "strict" that existing coal plants could not achieve them. Under the EPA plan, those companies would have to build new facilities, perhaps using different fuel. The Court held EPA's plan was not backed by clear congressional authority, and therefore, the plan was rejected.

Conclusion

Thus, it took decades to define and identify GHGs. While they are well-defined now, including the harm each gas causes, Congress has yet to put limits on their release. And where the EPA stepped in to regulate GHGs, many of those efforts to limit emissions have been rejected by courts.

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Endnotes

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Supreme Court Keeps Biden Administration's Social Cost of Carbon Plan in Place

Lauren Wilson


Credit: Phil Roeder

Intro

On May 26, 2022, the Supreme Court allowed the Biden Administration to continue to use its metric for determining the Social Cost of Carbon.[1] Many lawsuits have been filed over the belief that the government has a responsibility to monitor how the United States' emissions are contributing to climate change.[2] However, this suit arises from a different sentiment than most: that the government has gone too far in its attempts to calculate and regulate emissions. Louisiana, Mississippi, Alabama, and seven other states sued the Biden Administration in an effort to block the enforcement of a new policy regarding the Social Cost of Carbon and the role it plays in establishing environmental policy.

What Is the Social Cost of Carbon?

The Social Cost of Carbon (SCC) is a measurement in dollars of how much damage results from emitting one metric ton (mt) of carbon dioxide into the atmosphere.[3] This dollar amount enables policy makers to use a cost-benefit analysis to show when the benefits of preventing global warming are greater than the costs. The number plays an important role in determining the scope of specific environmental policies and regulations.

The SCC is calculated by analyzing the damage climate change has on the economy and human welfare. These damages include changes in agricultural productivity, human health, and cost of living.[4] There are four main steps in

making the calculation: 1) Predicting future emissions; 2) Calculating the effect these emissions will have on climate variables such as temperature; 3) Estimating the physical impacts on the climate and human welfare as well as monetizing those impacts; and 4) Discounting monetary damages to their respective year of emission.[5]

The fourth step in the calculation, applying the discount rate, greatly influences the SCC. A discount rate places a present value on costs that will occur in the future. The SCC discount rate is used to compare the value of future impacts on the environment to impacts experienced today. Some of the damages caused by climate change are expected not to become visibly problematic for decades. Therefore, according to the Environmental Protection Agency (EPA), the discount rate is needed in order to calculate the value of those future damages.[6] Considering the SCC is used to conduct a cost-benefit analysis regarding where and how to place regulations, the discount rate enables policy makers to quantify what should be spent today to avoid greater monetary damages in the future. The higher the discount rate, the lower the value of future damages are estimated to be.

Another factor affecting the SCC estimate is whether to consider how the United States' emissions contribute to climate change damage on a global scale. The EPA included the global impact because climate change itself is a global issue. However, some argue that the United States should not base its policies and regulations on global considerations.[7] Over the course of the past three administrations, there have been changes to exactly what the equation is and what is taken into consideration to form the estimates.

Administrative History of the SCC

In 2009, President Obama created the Interagency Working Group (IWG) and tasked it with calculating estimates for the Social Cost of Carbon and other greenhouse gases. Among other things, these estimates took into consideration the global impact that the United States' emissions had on the rest of the world. The estimates also applied a discount rate of around three percent. In 2010, the Obama Administration released its last estimate of the SCC to be $51 per metric ton, and in 2016 issued estimates for the Social Cost of Methane and Nitrous Oxide, two other greenhouse gases.[8]

When President Trump took office, he dismantled the IWG and instated new criteria for calculating the SCC.[9] Specifically, the Trump Administration removed global considerations from the equation to focus only the United States' emissions. Additionally, a higher rate of discount, around seven percent, was used to estimate future impacts of emissions. The change in formula caused the SCC to drop to as low as $1 mt. This low SCC allowed the Trump Administration to justify rolling back many of the environmental regulations set by prior administrations.[10] One example was replacing the Obama era Clean Power Plan (CPP), which was designed to reduce power plant carbon dioxide emissions by 32 percent.[11] The Affordable Clean Energy Rule which took the place of the CPP reduced greenhouse gas emissions from power plants by one percent.[12]

On January 20, 2021, President Biden issued Executive Order 13990.[13] This order reinstated the IWG and adopted the same method of calculation that the Obama Administration used. The Order also required the IGW to publish interim estimates for the Social Cost of Carbon. The IGW's interim estimates matched the 2016 calculation of $51 mt for the SCC.

Why Did Some States Sue?

The increase in the SCC estimates from $1 to $51 prompted the states to sue the federal government. Because the SCC is used to regulate carbon-emitting industries such as oil and gas drilling, the states believe that the estimates will be used to place heavy regulations on their most economically productive projects. The Attorney General for Louisiana, the nation's number two producer of oil and natural gas, stated that the new policy for estimates would "drive up the cost side of every regulatory action even touching greenhouse gas emissions."[14]

To bring suit, the states had to establish that they suffered an injury which was caused by the federal government and could be redressed by a ruling in their favor. For this injury, the states cited the negative impact to their revenues and economies that new regulations, justified by the SCC estimates, would cause. They also sought relief on the grounds that the interim estimates violate the requirements of the Administrative Procedure Act, that the President and IWG do not have authority to enforce the estimates, and that the federal government acted beyond its authority by basing the estimates on global considerations.[15]

The Trial Court's Opinion

The trial court ruled in favor of the states. As a result, the trial court restored the SCC to the estimates from the

Trump Administration and blocked the Biden Administration from enforcing its interim estimates and calculation policy. The court found that Biden's executive order and the new method for calculating the SCC did not comply with the Administrative Procedure Act or Circular A-4 (a guide on how to perform proper regulatory analysis). Additionally, the court sided with the states' position that global considerations were not enforceable since Congress has established that agencies should only consider national effects. The court cited various acts such as the Clean Air Act, the Energy Policy and Conservation Act, the Outer Continental Shelf Leasing Act, and more; none of which appear to authorize the use of global effects in their considerations.

The Court of Appeals Opinion

The federal government appealed, and the 5th Circuit Court of Appeals ruled to allow the Biden Administration to continue using its interim estimates and calculation policy. In its reasoning, the Court of Appeals stated that the Circular A-4 guidelines on proper regulatory analysis are not binding on any agency.[16] Therefore, the trial court should not have relied on this to stop the Biden Administration from enforcing its SCC policy.

Additionally, the Court of Appeals stated that the states' claimed economic injury resulting from the estimates was merely hypothetical and had not manifested. In other words, the method for calculating the estimates did not directly or immediately harm the states. There would need to be regulatory action taken as a direct result of the estimates for there to be sufficient injury. Agencies use many more factors than just the Social Cost of Green House Gases when determining when and how to regulate. So, to say that the interim estimates by themselves were directly responsible for any possible future injury was not accurate, according to the court.

Lastly, the Court of Appeals found that the federal defendants were harmed by the trial court's decision to ban the Biden Administration from using the interim estimates. As a result of the trial court's order to restore the estimates to those of the Trump Administration's, federal agencies were forced to comply with guidance from the previous administration. The court noted that it is beyond the authority of the federal courts to instruct a current administration's agencies to adhere to a previous administration's policies. The Court of Appeals did not comment as to the issue of including global considerations in the estimates.

The Supreme Court's Order and its Implications

The decision was appealed up to the Supreme Court which ultimately sided with the Court of Appeals. The Supreme Court, in a single sentence order, denied the states' request to block the use of the interim estimates.[17] While the states may challenge future regulations justified by the SCC, government agencies will now use the Biden Administration's SCC estimates in their future regulatory actions. This will help the Biden Administration to reach its goal for the United States to reduce greenhouse gas pollution by 50 percent before 2030.[18]

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Court Erases Largest Oil Lease Sale in U.S. History

Annika D. Rush

Introduction

The Gulf of Mexico, stretching across more than 600,000 square miles, boasts valuable American oil and gas reserves, which are leased to companies for exploration and production by the Bureau of Ocean Energy Management (BOEM) in the U.S. Department of the Interior. The Outer Continental Shelf Lands Act (OSCLA), enacted in 1953, declared the Outer Continental Shelf (OCS) in federal waters "a vital national resource reserve held by the Federal Government for the public."[1] This means that BOEM is tasked with balancing the competing Congressional interests of environmental conservation and lucrative oil and gas leasing.

The largest lease sale in American history, Lease Sale 257, proved to be problematic. A federal district court ruled that BOEM did not properly consider the total emissions from the project and vacated the agency's decision for Lease Sale 257, describing BOEM as "barreling full-steam ahead with blinders on."[2] As a result, leases will not be issued to the high bidders and no further stages (such as exploration and development) will occur.

Lease Sale 257

BOEM's 2017-2022 Lease Program for oil and gas exploration and development included 10 lease sales in the Gulf of Mexico, with Lease Sale 257 being for the largest tract of land.[3] Lease Sale 257 would allow exploration and development of 80.8 million acres in the OCS, with tracts being divvied up between multiple developers. Lease Sale 257 produced more than $191 billion dollars in bids, making it the largest oil and gas lease sale in American history.[4] While bids were taken for the Lease Sale, the leases were not awarded or executed.

BOEM produced three different Environmental Impact Statements (EISs) for different steps during the 2017-2022 Lease Program. First, BOEM produced an EIS for the entire program in 2016, indicating it would supplement its environmental analysis on a regular basis. In 2017, BOEM published a Multi-Sale EIS which considered the environmental impacts of several specific lease sales, including Lease Sale 257. Additionally, BOEM published a 2018 Supplemental EIS which evaluated two other lease sales of the 2017-2022 Lease Program. In late 2020, three years after the EIS evaluating Lease Sale 257, BOEM published a notice that it was moving forward with that lease sale. The notice stated that the three EISs were a sufficient review under the National Environmental Policy Act (NEPA) of Lease Sale 257 and no supplemental EIS was required.[5]

NEPA and Oil Leasing

Leasing in the OCS is regulated by NEPA,[6] which forces federal agencies to take a "hard look" at the environmental consequences of all major actions. NEPA requirements are intended to be completed prior to final agency decision and before environmental impacts occur. An agency should prepare an EIS when it determines its actions are likely to result in adverse environmental effects. When producing the EIS, the agency must consider reasonable alternatives to its planned action, including a No Action Alternative which analyzes the environmental impacts as if the planned program did not take place.

However, NEPA does not require the agency to choose the option least harmful to the environment. In other words, NEPA requires a full analysis of environmental impacts but does not require a specific agency action once that analysis has been performed. If the agency fails to consider a major environmental impact when calculating the environmental consequences of its actions, the required hard look under NEPA has not been met. In such a case, a court can declare the EIS to be inadequate and vacate the agency decision that relied upon that EIS.

The Lawsuit

Environmental groups sued BOEM, challenging the adequacy of the NEPA review for Lease Sale 257.[7]


Credit: Jeff Miller

The groups argued that BOEM did not consider all the environmental impacts of the proposed action, notably, that the emissions calculations it was relying on were incorrect.

The proposed action would allow petroleum to be developed, resulting in emissions from the production of the oil and also emissions from the consumer's use of that oil, known as "downstream emissions." According to the court, downstream emissions typically account for the bulk of greenhouse gas emissions from a lease sale. The court agreed with the environmental plaintiffs that BOEM failed to consider important variables in its analysis of downstream emissions, and thus could not satisfy the required hard look under NEPA.

To calculate the downstream emissions for the program, BOEM used a computer model known as the MarketSim.[8] The model concluded emissions would be higher if BOEM did not have lease sales. To reach this conclusion, the model relied on certain input. First, the model assumed that foreign production of oil and gas would have to take the place of the domestic production from Lease Sale 257. Second, the model assumed that the production of that replacement foreign petroleum would emit more greenhouse gases than domestic production. This is because the foreign gas would have to be transported to America and also because some foreign countries may not have the same environmental controls in place that American production requires. Third, the model assumed that foreign demand for oil and gas would be unchanged regardless of whether the oil was produced domestically or abroad.

The assumption that emissions would be lower by conducting Lease Sale 257 was based on the premise that foreign-produced petroleum would be consumed in the place of domestic oil at the same rate and likely would produce more greenhouse gases. The court found this assumption to be faulty – in part because the price of foreign petroleum would be higher, reducing demand, thereby reducing consumption and emissions.

The court also took issue with BOEM's using the MarketSim Model which had been deemed arbitrary and capricious by two other courts for leading to faulty conclusions on environmental impacts.[9]

The court was unpersuaded by BOEM's argument that it was not required to consider downstream effects of emissions at the lease sale stage because those emissions were speculative. The court agreed that some speculation may be required, but it found that the data and methodology to correctly calculate the emissions were already in the record and did not depend on site-specific information. Leaving the information out "undermined the reliability" of the conclusion on emissions. For example, even though BOEM had identified a decrease in "foreign oil consumption … over the duration of the 2017-2022 Program," it excluded those data from the total emissions calculations.[10]

Notably, the three EISs prepared for the program all relied on a Report which estimated a reduction in foreign demand.[11] BOEM assessed a foreseeable and quantifiable reduction in the demand for petroleum, therefore, according to the court, it should have been able to assess the corresponding change in emissions. Further persuading the court that this was not unreasonably speculative, BOEM estimated a reduction in foreign demand in preparing for the very next lease sale (Lease Sale 258). The court reasoned that if BOEM could perform these calculations correctly in September 2021, they could have done so a year before.

The court declared the NEPA evaluation (the three EISs) to be inadequate. BOEM's exclusion of foreign demand of oil from the total emissions calculation was deemed an arbitrary action. The court reasoned that it was arbitrary to identify an issue as important but exclude it from the total emissions calculation. The exclusion of foreign demand data completely changed the calculations that BOEM relied on for the lease program, so the court vacated the agency's record of decision for Lease Sale 257. As a result, BOEM did not award or execute the leases to the developers to begin exploration and production activities despite accepting bids. The court found that the claims of economic loss by the State of Louisiana and the American Petroleum Institute, which had joined the suit as defendants, were speculative at this stage of the process.

The Appeal

Efforts to revive the $191 billion dollar deal began shortly after the district court's decision. The American Petroleum Institute and the State of Louisiana filed appeals in June 2022.[12] Their briefs challenge the trial court's analysis of NEPA's extraterritorial reach, arguing that foreign emissions were not required to be considered in an EIS at the lease sale stage because downstream emissions are "years away" and the effects of climate change are "more speculative than the possibility of oil spills." If the ruling stands, it could expand how federal agencies are required to consider downstream environmental effects outside of American territory.

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The Applications of Digital Twinning for Climate and Resilience Planning

Stephen Deal

In order to address environmental problems, city governments are increasingly turning to a new tool: digital twinning. A digital twin is a living digital replica of a city that is continuously updated with real-time data and analytics on the physical, social and human interactions that occur in a city. One might liken the system to a video game in which players make planning decisions, such as what ordinances and land use patterns to implement, and watch their decisions play out in real time as their city simulation grows or declines based upon player inputs. A digital twin is not a substitute for traditional planning, but its ability to gauge multiple impacts in a simulation makes it a powerful tool for cities in the 21st century.

Digital Twinning in Practice

Digital twins can be defined as "intelligent adaptive systems that pair virtual and physical worlds."[1] A digital twin is more than just a virtual model of a city though; it is a model that cities can use to run simulations on everything from new policies to proposed infrastructure projects. Though many cities are in the early stages of building their own digital twins, the firm ABI Research estimates that by 2025 more than 500 city digital twins will be up and running across the world.[2]

To properly maintain a digital twin, a city must be able to combine multiple layers of data.[3] As described by Hurtado and Gomez in their article, *Mirror Mirror,* the base layer will consist of terrain information, while the layer above that will be building information modeling data that includes all city buildings. The middle portion of the model will consist of two additional layers: one to capture the infrastructure system of the city and another layer for mobility, which includes the physical transportation elements (roads, sidewalks). The final two layers are critical as they are the key drivers in the data collection and analysis process. By employing sensors across the city, local governments are able to gather real-time data on the layers below and they have an effective method for continually monitoring city systems and services. This sensor data constitutes its own layer, and because it is continually updated and monitored it helps drive the simulation work done at the highest layer. The top layer is the digital twin layer, the culmination of all the previous data compilations.

Arguably the most prominent example of twinning at this time is Virtual Singapore. The model employs 14 core datasets ranging from land use to underground utilities grabbed from "more than 3 million street-level images captured at street level and 160,000 images taken from the air."[4] What distinguishes this twin from past urban modeling efforts, is the intricate level of detail at the user's fingertips. The model distinguishes buildings from trees and minute urban details such as windows, rooftops and building facades are treated as unique assets within the model. The full level of data available through Virtual Singapore is not only significant for planners though, it is also significant to research and development.[5] The model can serve as a common digital platform for analysis and research. Previous collaborative efforts between cities and academia would often require significant time to simplify modeling and data processes used and translate that work into something practitioners could easily grasp and make use of. By employing a digital twin, the experimentation and testing within a project can be easily visualized and validated as stakeholders can better grasp how data variables flow and interact within the twin.

Environmental Applications of Twinning

One of the biggest positives of twinning is that it allows planners to view the city as a kind of dynamic organism, one that evolves in response to a wide variety of inputs, both seen and unseen. By utilizing digital twinning, planners have a valuable tool as they can measure a city's capacity for change. The chief executive of the firm which developed

Virtual Singapore, noted that by using real-time data a more holistic perspective becomes possible:

> The problem is that when we decide about the evolution of the city we are in some way blind. You have the urban view of it – a map – you decide to put a building here, but another agency has to think about transport....The creation of one thing changes so many other things – the flow and life of citizens.[6]

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Though past planning endeavors have captured certain discrete facets of the urban experience for evaluation, the "flow of life" was something that remained elusive. Now through digital twinning, planners have a model which can roughly approximate that flow and can project it out into the future for policy analysis.

This type of analysis of city flow and movement has profound implications in the drive to builder greener cities. Environmental attributes are fickle and can change considerably over a short period of time. Different areas of a city may have better exposure to sunlight or be prone to higher wind speeds, which have profound implications for renewable energy development. Urban air quality is also highly variable, as warmer temperatures increase the production of ground-level ozone, which is a major factor in smog.[7]

Through digital twinning, cities can track these variable environmental factors and gain insight into how they interact with each other over a given period of time. Cities such as Los Angeles, Las Vegas, Phoenix, and New York are building digital twins to lower building emissions as part of the Clean Cities – Clean Future campaign from the software company Cityzenith. For example, in Las Vegas, street-level LIDAR (Light Detection and Ranging Sensors) data are being collected from sensors positioned across the city.[8] Using LIDAR sensors, the city can capture loads of data on street use and movement patterns, such as "whether a moving object is a pedestrian, vehicle, or bicyclist." This data can then be aggregated into a digital twin, which would gauge air and noise pollution. This can be accomplished by tracking sound levels and electricity usage. Since EV vehicles generally generate less noise than the average car that data can be captured and tracked across the city. A twin can also track important energy variables such as electrical grid load distribution and water management.

The applications of digital twinning are not simply limited to large metropolises though, smaller cities are getting in on the practice as well. In Ithaca, New York, town leaders are partnering with Cornell researchers to develop a digital twin to help manage local decarbonization efforts.[9] In total, Ithaca is home to around 8,000 buildings, ranging from new research buildings to 19th century residences. City energy use data from Ithaca will be paired with a dataset from the US Department of Energy that contains building profiles data. This profile data will help in capturing occupant behavior and energy uses within spaces. The twin will also capture critical data on the city's energy grid, such as the grid's existing capacity and what type of green energy sources the grid is utilizing. Cornell researchers are also obtaining building permit data from the city to determine how individual buildings are constructed. This will help building owners visualize the potential carbon savings associated with building retrofits and materials reuse.

Digital Twinning Comes to the Gulf

In the Gulf Coast region, a digital twin is being used for yet another important set of environmental issues: flooding and hazard mitigation. This two-year research project is made possible by funding from Texas Sea Grant, who will also be working with the project team to ensure that the data reaches critical coastal stakeholders. The proposed platform, known as AI-Based Roadway Flooding Digital Twinning or AIR-FLOOD for short, would assist coastal communities in Texas with storm evacuation procedures.[10] The project team, led by Dr. Kunhee Choi with Texas A&M University, will collect data across two broad categories, or pillars.

The first pillar will consist of flood mapping data. Relevant datasets in this category include: FEMA flood maps, a roadway inventory, high-resolution digital elevation data, and Hazus model data with detailed information on economic and structural damage associated with specific flood events.[11] The second pillar will be roadway assessment data. This pillar will include datasets such as: roadway inventory data from Texas DOT, pavement performance data for communities in the study area, and traffic volume data. Using datasets from these two pillars, the team will then work on building a web-based digital twinning platform.

By utilizing twinning, the project will be able to combine flood modeling and roadway damage prognostics in a way that will help coastal communities respond more quickly and dynamically to flood events. When completed in 2024, the platform will provide first responders with critical data on the best possible evacuation routes in the event of an extreme flooding event. The twin could also help local and state transportation agencies prioritize emergency roadway repair projects.

Conclusion

The potential planning applications for digital twins are considerable. The extraction process for high-quality digital data, which used to be static and on an as-need basis, now has the potential to be constant and ongoing through the use of a digital twin. More importantly the flow of data in a twin can adapt to assess different policy approaches or if a shift in modeling becomes necessary because of new growth. By utilizing twinning, planners no longer have to be satisfied with isolated statistical snapshots to capture urban change over time, they can make use of a model that approximates the flow and life of the urban realm.

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Endnotes

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In Sum.

A Summation of the Facts and Figures of Interest in this Edition

★ *Percentage of all greenhouse gases that are CO_2, by weight:*	79
★ *Cost of CO_2 on human health and the economy per metric ton:*	$51
★ *High bid total for Gulf of Mexico Lease Sale No. 257:*	$191,688,984
★ *Rank of Gulf of Mexico Lease Sale No. 257, historically:*	1
★ *Estimated number of cities that will have digital twins in 2025:*	500

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Mississippi-Alabama Sea Grant Legal Program
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WATER LOG (ISSN 1097-0649) is supported by the National Sea Grant College Program of the U.S. Department of Commerce's National Oceanic and Atmospheric Administration under NOAA Grant Number NA18OAR4170080, the Mississippi-Alabama Sea Grant Consortium, the State of Mississippi, the Mississippi Law Research Institute, and the University of Mississippi Law Center. The statements, findings, conclusions, and recommendations are those of the author(s) and do not necessarily reflect the views of the Mississippi-Alabama Sea Grant Legal Program, the Mississippi-Alabama Sea Grant Consortium, or the U.S. Department of Commerce. The U.S. Government and the Mississippi-Alabama Sea Grant Consortium are authorized to produce and distribute reprints notwithstanding any copyright notation that may appear hereon.

Recommended citation: Author's name, *Title of Article,* 42:3 WATER LOG [Page Number] (2022).

MASGP-22-003-03

ISSN 1097-0649 *September 2022*

WATER LOG is a quarterly publication reporting on legal issues affecting the Mississippi-Alabama coastal area. Its goal is to increase awareness and understanding of coastal issues in and around the Gulf of Mexico.

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