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CONTENTS

Delivering Climate Responsive Resilient Building Codes and Standards – Policy Issues

International Code Council

Introduction

Communities are becoming increasingly vulnerable to the detrimental impacts associated with a changing climate. As natural hazards continue to intensify in magnitude and occurrences, it is critical for communities to adapt to their unique and changing risks. The development of building codes that draw on both building science and climate science have been identified as an essential strategy to improve the resilience of buildings and communities to intensifying risks from weather-related natural hazards.

The Global Resiliency Dialogue, a voluntary collaboration of building code developers and researchers from Canada, Australia, New Zealand, and the United States, came together to identify strategies and research needs to effectively address evolving climate risks in codes and standards. The Dialogue's aim is to create an international resiliency guideline and enable collaborative research efforts that will aid jurisdictions across the globe to better prepare the building stock to withstand the more extreme weather events, including high wind, flooding, and wildfire, that the evidence and science tells us have been and will continue to increase in frequency and duration.

In February 2021, the Global Resiliency Dialogue published findings of its first international survey in the report, ***The Use of Climate Data and Assessment of Extreme Weather Event Risks in Building Codes around the World.*** A second international survey was conducted to capture feedback on current barriers and potential strategies to incorporate future-focused climate science and risk in building codes and standards. A summary of the results from across the member countries is captured in *Delivering Climate Responsive Resilient Building Codes and Standards.* This report captures the viewpoints of U.S. stakeholders who participated in the international survey.

This article was adapted with permission from "Delivering Climate Responsive Resilient Building Codes and Standards," a report based on the findings of the Global Resiliency Dialogue and published by the International Code Council.

Policy Issues

Policy Implementation

The central challenge for policymakers is balancing cost, mitigation and resiliency. The model building codes which exist already provide reasonable requirements to ensure resiliency, and can be strengthened based on need and risk level through overlays for stretch requirements. The "above code" provisions certainly increase the up-front costs, tasking policymakers to promote a long-term outlook that considers true life cycle costs. This of course varies based on building type, but also forces an examination of who ***truly*** bears the costs of non-resilient buildings. This can be achieved by a clear analysis of risks and rewards on a project-by-project basis.

Some suggest that investors should require service life accounting and risk modelling for every project, and according to a recent **Urban Land Institute report**, investors are looking for better data and frameworks to more quantitatively understand and compare risk at a market level to understand whether local investment in resilience is sufficient to mitigate the level of physical risk faced.

Policy Advancement

There are some jurisdictions in the United States that are already making great progress – by necessity – in increasing the rigor of their building codes to ensure greater resilience and providing best practice examples for the rest of the country. New York City has updated its building codes twice since "Superstorm Sandy" to increase freeboard requirements, and more work is underway to introduce larger resilience innovation into the local building codes. The city of

Renewable Natural Resources Foundation

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Norfolk, Virginia has completely overhauled its zoning codes as part of its future-focused **Resilience Strategy**. In 2018, the City of Virginia Beach **denied an application** for a residential development proposal that met technical requirements, but was located in an area threatened by increased flood risk due to expected sea level rise.

Some have suggested that regulation should not prescribe the ways in which to achieve resilience. Local governments should instead determine what is financially feasible based on the risk to their particular jurisdiction. The strengthening of resilience provisions in building codes is most effectively done at the local level, depending upon the level of hazard identified for that locality. However, enhancing model codes or moving to "above code" or "stretch code" solutions can be politically charged especially at the local level. To provide some political cover, the approach taken with earthquake provisions could provide some insight. In this case, earthquake provisions were effectively strengthened following federal-level leadership coupled with a community of design professionals who defined standards and guidelines based on hazard level.

Complementary Resilience Tools/Activities

A clear communication strategy that embraces risk-based information, based on the same set of facts (i.e. acknowledging that climate change is real), from a unified group of climate and building scientists, presented in clear language would also prove very useful to policymakers. Such a strategy, coupled with supporting policy incentives and disincentives, could likewise be used to educate buyers to demand resilience in their investments, and reject investments that are not adequately resilient.

Policymakers can also have a huge impact by preventing overdevelopment and discouraging building in high-risk areas (which has not always been done in the past), while enabling people to relocate to areas and/or buildings of greater resilience – essentially making resilience more equitable. This can be achieved through clear cost-benefit analyses utilized by the policymakers and clearly communicated to the general public. This could result in the reconsideration of land use, coastal development and managed retreat policies.

Expanded development and use of building-level resilience benchmarks that can be understood by the public could provide a powerful incentive for builders and developers to exceed code requirements, driven by public demand.[1]

Similarly, some of the existing tools that are commonly used may be due for rethinking, such as Certificates of Occupancy (COO). Typically issued upon completion of construction, this COO process does not allow for the easy imposition of retroactive requirements.

Addressing Legacy Issues

Policies and incentives that target resiliency in the existing building stock are also a big part of the equation. Subsidies and tax credits for physical improvements to buildings as well as to compensate volunteers for time spent undertaking neighborhood improvements are widely cited as strong drivers to encourage wide-scale resiliency improvements. Likewise, a whole-community approach to resiliency, utilization of resiliency rating systems, and tying improved resiliency into correcting historical inequities and removing people from harm's way, are all suggested policy pathways.

Several examples of successful incentive programs were cited as well, including Enterprise Community Partner's **Keep Safe** guide targeted to homeowners and multifamily property owners and the general public in Caribbean island communities and South Florida to individually promote and implement resilience strategies, and the U.S. Department of Energy's **Weatherization Assistance Program** which provides assistance to low-income households to increase the energy efficiency of their homes, thereby reducing energy costs.

Social Equity Concerns

Policies driven by the desire for greater social equity are likely to drive implementation of resilience initiatives. In the U.S., land development topics have a complex history, which in the resiliency discussion involve communities that lack rank, access, and privilege being disproportionately affected by hazard events while owners of coastal vacation homes receive compensation for the losses in their second and third homes. These issues and their historical context are addressed at length in the book, **"Geography of Risk"** by Gilbert Gaul.

Resiliency efforts – and lack of them – have a disproportionately strong impact on these already marginalized communities, including older and poorer members of society who are least able to relocate or fortify their buildings. The City of Norfolk, Virginia recognized and factored this into its **Resilience Strategy**.

Equity was also a driving factor within the 2018 Federal Alliance for Safe Homes publication, ***Learning from the 2017 Disasters to Create a Reliably Resilient U.S.***, which argued that building for resilience is essential to achieve numerous societal goals, including:

- Promoting the embrace of resilience "across the board with no exceptions, no seasons, and no compromise;"
- Combating the six core biases identified in the *Ostrich Paradox:* myopia, amnesia, optimism, inertia, simplification, and herding;
- Encouraging the use of "modern, model building codes, standards, and floodplain regulations that are adopted on time and effectively enforced are non-negotiable;"
- Repeating the core messages of living resiliently and safely;
- Improving communication to people and communities and leaders before, during, and after disasters, facilitating a two way conversation;

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[1] Current building-level resilience rating systems in the U.S. include **RELi** for multiple hazards while the **U.S. Resiliency Council** and REDi support seismic resilience assessments. At the community level, the **Alliance for National & Community Resilience** (ANCR) includes a buildings benchmark in its Community Resilience Benchmarks.

- Making disaster planning more inclusive (old and poor people especially have trouble);
- Not forgetting lessons learned from past disasters so that cycle of Build-Destroy-Rebuild can be broken; and
- Recalling that the costs (economic and societal) of disaster can be decreased by better codes.

Cost, Mitigation, and Resilience

Data that demonstrates the benefit-cost ratio of investments in resiliency, including consideration of the impact of increased waste and debris from damage would be helpful to show the value of investing in resilience. However, in the U.S., the current economics of residential construction do not incentivize resilience. Rather, the focus is on low first cost-of-use, rather than lifecycle costs, and aesthetics, rather than built-in resilient attributes. Regulation that incentivizes resilient construction is needed, and bailouts at the federal level that disincentivize resilient construction need to be more surgically applied.

The complete report "Global Resiliency Dialogue Second Survey of Building Stakeholders – USA" can be found **here**.

The summary report "Delivering Climate Responsive Resilient Building Codes and Standards: Findings from the Global Resiliency Dialogue Survey of Building Code Stakeholders in Canada, Australia, New Zealand and the United States" can be found **here**.

Ocean Deoxygenation: Everyone's Problem

International Union for Conservation of Nature

Breathing water is hard work as a given volume of water holds far less oxygen than the equivalent volume of air. This makes the physiological performance and behavioural repertoire of marine organisms heavily dependent on their ability and capacity to extract oxygen from the ambient sea water. Ocean deoxygenation generally affects marine organisms as soon as conditions depart from full aeration, with downstream consequences on their activities and capacity to face natural contingencies. The importance of maintaining adequate levels of oxygen in the ocean is perhaps best summarized by the motto of the American Lung Association: "if you can't breathe nothing else matters."

Whilst the focus of actions on trying to clean-up the ocean is on the impacts from pressures such as fishing, pollution, habitat destruction, invasive species and plastic, there is no environmental variable of such ecological importance to marine ecosystems that has changed so drastically in such a short period of time as a result of human activities as dissolved oxygen. Hypoxia – a condition that deprives an organism of adequate oxygen supply at the tissue level – is one of the most acute symptoms of the reduction in dissolved oxygen. The present-day losses of oxygen in the ocean – ocean deoxygenation – is starting to progressively alter the balance of life, favouring hypoxia-tolerant species at the expense of hypoxia sensitive ones.

Working with 67 scientific experts from 51 institutes in 17 countries, what is presented here is the largest peer-reviewed study conducted so far on ocean deoxygenation. Expressed in the words of the world's leading scientists on this topic it shows the inescapable fact human activities are now driving life sustaining oxygen from our ocean-dominated planet. Society needs to wake up – and fast – to the sheer enormity of detrimental changes we are now causing to the Earth's regulatory systems, and the now near-monumental efforts that will be needed by governments and society to overcome and reverse such effects. This report is probably an underestimation of what is happening now. Science is incomplete and awareness of ocean deoxygenation is just happening, but what is already known is very concerning.

The loss of oxygen in the ocean can broadly be put down to two overlying causes – eutrophication as a result of nutrient run-off from land and deposition of nitrogen from the burning of fossil fuels, and the heating of ocean waters as a result of climate change, primarily causing a change in ventilation with the overlying atmosphere so that they hold less soluble oxygen, and compounded by reduced ocean mixing and changes in currents and wind patterns. Ocean deoxygenation is but the latest consequence of our activities on the ocean to be recognized. Ocean warming, ocean deoxygenation, and ocean acidification are major 'stressors' on marine systems and typically co-occur because they share a common cause.

Increasing carbon dioxide emissions into the atmosphere simultaneously warm, deoxygenate, and acidify marine systems, whilst nutrient pollution also contributes to increases in the severity of deoxygenation and acidification. As a result, marine systems are currently under intense and increasing pressure from the cumulative effects of these multiple stressors, and with current sustained trajectories expected for greenhouse gas emissions the changes in the ocean will only continue and intensify. Awareness of these phenomena, on top of existing issues such as overfishing, pollution and habitat destruction, has begun to trigger significant concern on the impacts on marine biodiversity and the functionality of the ocean as a whole, and how this may influence factors such as weather, crop success and water supplies, and then affect people everywhere.

In the last 65 years we have come to realize that over-enrichment of waters with nutrients or organic matter (eutrophication) is a problem that threatens and

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*This article is an excerpt from the executive summary of the International Union for Conservation of Nature's report "Ocean deoxygenation: Everyone's problem." The full report can be found **here**.*

degrades coastal ecosystems, alters fisheries, and impacts human health in many areas around the world. Over 900 areas of the ocean around the world have already been identified as experiencing the effects of eutrophication. Of these, over 700 have problems with hypoxia, but through improved nutrient and organic loading management on adjacent land about 70 (10%) of them are now classified as recovering. The global extent of eutrophication-driven hypoxia and its threats to ecosystem services are well documented, but much remains unknown as to the long-term human health, social, and economic consequences.

What is particularly new with this report is the additional focus on the more recently recognized effect of lowered oxygen resulting from ocean warming, which is now affecting enormous areas of the ocean. The atmospheric warming resulting from greenhouse gas emissions being taken up in ocean water is now driving vast changes in the physical and biological make-up of the sea. The two causes also interact, with warming-induced oxygen loss tipping coastal areas into eutrophication-driven hypoxia and may contribute to the dramatic increase in regards of coastal hypoxia. The combination of eutrophication-driven hypoxia, which can be relatively easily and quickly reversed if the necessary measures are put in place, and hypoxia due to climate change driven warming, that can't easily be reversed – if at all – is causing the emergence of ocean deoxygenation as a new issue of global significance.

Human activities have altered not only the oxygen content of the coastal and open ocean, but also a variety of other physical, chemical and biological conditions that can have negative effects on physiological and ecological processes.

At regional to local scales the overall concerns about ocean deoxygenation are further exacerbated by outbreaks of Harmful Algal Blooms. The development of hypoxic or anoxic waters is regularly listed as one of the consequences of algal blooms. Such events of low oxygen associated with harmful algal blooms are characterized by high initial oxygen concentrations, exceptional rates of respiration following bloom senescence and short timescales. The coastal environments subject to high biomass harmful algal blooms and associated events of low oxygen are typified by elevated inorganic nutrients because of either natural or cultural eutrophication.

In the short term, marine organisms respond to ocean deoxygenation through changes in their physiology and behaviour. Alteration in feeding behaviour and distribution pattern are classically observed, potentially leading to reduced growth and to more difficulties completing their life cycle. Vertical habitat compression is also predicted for organisms in the upper ocean. In the medium term, epigenetic processes (non-genetic influences on gene expression) may possibly provide marine populations with a rapid way to acclimate to the rapidly changing oxygenation state. However, this developing field of biological sciences is too recent for a full evaluation of the contribution of epigenetic responses to marine organisms' adaptation to ocean deoxygenation to be made. Changes in the phenology (timing of life stage-specific events) of marine species, related to ocean deoxygenation have not yet been observed. However, deoxygenation generally co-occurs with other environmental disturbances (ocean warming and acidification) which are also liable to affect marine species' life cycles. The lack of understanding of their interactions and synergies currently restricts our ability to assess marine populations' capacity to phenologically respond to ocean deoxygenation.

The overall consequences of perturbations to the equilibrium state of the ocean-atmosphere system over the past few decades are that the ocean has now become a source of oxygen for the atmosphere even though its oxygen inventory is only about 0.6% of that of the atmosphere. Different analyses conclude that the global ocean oxygen content has decreased by 1-2% since the middle of the 20th century. There is good evidence that ocean temperature increases explain about 50% of oxygen loss in the upper 1000 m of the ocean, but there is less confidence of the knock-on effect on respiration – another factor to explain lowered oxygen. Less than 15% of the oxygen decline can be attributed to warming-induced changes in respiration of particulate and dissolved organic matter.

Most of the oxygen loss has been caused by changes in ocean circulation and associated ventilation – gas exchange – from the ocean into the atmosphere with oxygen from the ocean surface. As the ocean warms from the surface, stratification is expected to increase, with a tendency for a slowing down of the ocean circulation. A slowed down circulation is expected to account for up to 50% of the observed deoxygenation in the upper 1000 m, and for up to 98% in the deep ocean (> 1000 m depth). Spatial patterns and individual mechanisms are not yet well understood. The current state-of-the-art models available predict deoxygenation rates only half that of the most recent data-based global estimates. Human activities have altered not only the oxygen content of the coastal and open ocean, but also a variety of other physical, chemical and biological conditions that can have negative effects on physiological and ecological processes.

The ocean as a whole is expected to lose about 3–4% of its oxygen inventory by the year 2100 under a "business-as-usual" scenario (RCP8.5) with most of this loss concentrated in the upper 1000 m where species richness and abundance is highest.

Further climate-driven warming of bottom waters may also result in enhanced destabilization of methane gas hydrates, leading to enhanced release of methane from sediments, and subsequent aerobic respiration of methane to carbon dioxide. There is, however, little observational evidence for a warming-induced acceleration of methane release taking place already. As the ocean continues to warm, it will lose yet more oxygen due to the direct effect of temperature on gas solubility, as warmer waters hold less soluble gas. Additionally, reductions in vertical mixing associated with enhanced upper-ocean buoyancy stratification will also occur leading to respiration-driven oxygen depletion at depth. The ocean as a whole is expected to lose about 3–4% of its oxygen inventory by the year 2100 under a "business-as-usual" scenario (RCP8.5) with most of this loss concentrated in the upper 1000 m where species richness and abundance is highest.

The future intensification and expansion of low oxygen zones (LOZ) can have further ecosystem consequences as oxygen dependent cycling of elements by microbes alter the supply of nutrients or in extreme cases, lead to increased production of toxic hydrogen sulphide gas. Low oxygen conditions and increased temperature jointly limit the viable habitat for marine macro- organisms. Continued ocean warming accompanied by deoxygenation will drive habitat contraction and fragmentation in regions where oxygen levels decline below metabolic requirements. Expansion of suboxic zones will likely disrupt the cycling of nitrogen in the ocean; denitrification may increase, yielding greater rates of fixed nitrogen loss from the ocean. Perturbations to the nitrogen cycle may include substantial changes to nitrous oxide production, though this is currently highly uncertain.

It is predicted that there will be distinct regional differences in the intensity of oxygen loss as well as variations in ecological and biogeochemical impacts. There is consensus across models that oxygen loss at mid and high latitudes will be strong and driven by both reduced solubility and increased respiration effects. Projections are more ambiguous in the tropics, where models suggest that there will be compensation between oxygen decline due to reduced solubility and oxygen increase caused by reductions in cumulative respiration. Thus, oxygen concentrations in the core of present-day oxygen minimum zones may increase; however, the total volume of waters classified as "suboxic" and "hypoxic" is still likely to grow substantially.

While the biogeochemical and physical changes associated with ocean warming, deoxygenation and acidification occur all over the world's ocean, the imprint of these global stressors has a strong regional and local nature.

Perhaps the most familiar areas subject to low oxygen are the Baltic Sea and Black Sea. These are the world's largest semi-enclosed low oxygen marine ecosystems. While the deep basin of the Black Sea is naturally anoxic, the low oxygen conditions currently observed in the Baltic Sea have been caused by human activities and are the result of enhanced nutrient inputs from land, exacerbated by global warming. The impacts of deoxygenation are not though limited to enclosed seas. The eastern boundary upwelling systems (EBUS) are some of the ocean's most productive biomes, supporting one-fifth of the world's wild marine fish harvest. These ecosystems are defined by ocean currents that bring nutrient-rich but oxygen-poor water to coasts that line the eastern edges of the world's ocean basins. As naturally oxygen-poor systems, EBUS are especially vulnerable to any changes in global ocean deoxygenation and so what happens to the oxygen content of EBUS ultimately will ripple out and affect many hundreds of millions of dependent people.

Oxygen limited waters, hypoxic and even anoxic conditions are now found in many coastal areas in the Atlantic Ocean including in connected seas like the Mediterranean, the Gulf of Mexico, and as previously mentioned the Black Sea, and Baltic Sea. Alongside this, large ocean basins such as the equatorial and southern Atlantic are being affected by decreasing oxygen levels, although studies show that such conditions were present in deep waters long before anthropogenic activities started to have an influence on the marine environment. In addition to many coastal waters of the Atlantic, oxygen-limited waters are also found at mid-water depths in most of the Atlantic Ocean basins, usually at 300 to 1000m. The oxygen concentrations in these areas have decreased during the last 60 years, partly due to ocean warming, partly as a result of decreased mixing and ventilation.

Elsewhere the low-oxygen zones of the Indian Ocean are expected to continue to expand and intensify. There does, however, remain a critical lack of information from potential hotspots for deoxygenation, including the mouths of the Indus, Ganges-Brahmaputra, and Irrawaddy rivers. Thus, pictorial representations of the current extent of ocean deoxygenation almost certainly underplay the effects being experienced in the world ocean. Capacity building and networking are needed to expand/improve monitoring of deoxygenation and other impacts of global change in the ocean.

It is currently difficult to predict – if at all – whether marine species will be able to adapt successfully to the changes now being observed in dissolved ocean oxygen. In the long term, adaptation through natural selection may occur in species with very short generation times. This is, however, far more difficult to envisage in most commercial fish species which are characterized by long generation times, especially given the fast-changing ocean conditions.

This report should accordingly be of interest and concern to everyone. It is intended to spur additional interest in the underlying research needed, especially as we enter the United Nations Decade of Ocean Science for Sustainable Development (2021-2030). The focus of this decade is to support efforts to reverse the cycle of decline in ocean health, so awareness of ocean deoxygenation is very timely. The Decade of Ocean Science is also intended to align ocean stakeholders worldwide behind a common framework that will ensure ocean science can fully support countries in creating improved conditions for sustainable exploitation of the ocean.

The scientific community is already concerned about and acting on ocean deoxygenation. The Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO) established the Global Ocean Oxygen Network (GO2NE), which is committed to providing a global and multidisciplinary view of deoxygenation, with a focus on understanding its multiple aspects and impacts. It is this network which has largely contributed to the production of this report. At the 2018 Ocean Deoxygenation Conference the 300 attending scientists from 33 counties published the "Kiel Declaration". This Declaration, with the subtitle 'the ocean is losing its breath', calls on all nations, societal actors, scientists and the United Nations to raise global awareness about ocean deoxygenation, take immediate and decisive action to limit pollution and in particular excessive nutrient input to the ocean, and to limit global warming by decisive climate change mitigation actions. This Declaration now needs to be heard loud and clear by policy advisers, decisions makers ocean users and the general public.

This report on ocean deoxygenation is perhaps the ultimate wake-up call needed to dramatically raise our ambitions to tackle and immediately curb our emissions of carbon dioxide and other powerful greenhouse gases such as methane. This is needed before human actions irreparably impact and change the conditions favourable for life on earth, and that drive and underpin the natural values we all hold close in our daily lives.

California Statewide Microplastics Strategy

California Ocean Protection Council

Editor's Note: This article is adapted from the February 2022 report "Statewide Microplastics Strategy: Understanding and Addressing Impacts to Protect Coastal and Ocean Health," published by the California Ocean Protection Council in consultation with the interagency Plastic Pollution Steering Committee (PPSC) and advisors from the California Ocean Protection Council Science Advisory Team, the Ocean Science Trust, the Southern California Coastal Water Research Project Authority, and the San Francisco Estuary Institute. This strategy is the first comprehensive government framework to address microplastic pollution and can serve as a model for future strategies. This adaptation includes background information about microplastics and the development of California's strategy, as well as immediate solutions and research priorities that could be adopted universally.

Background

Plastics are ubiquitous in both Californians' daily lives and in the environment. Worldwide, an estimated 11 million metric tons of plastic enter the ocean each year, and without any intervention, this amount is anticipated to triple by 2040. Plastics are recognized globally as the most harmful and persistent fraction of marine litter, accounting for at least 85 percent of total marine waste. Over time, plastics break down in aquatic environments into pieces of ever-decreasing size, with those less than 5 mm in size known as microplastics.

Microplastics fall into two general categories: primary microplastics manufactured at a small size (e.g., preproduction plastic pellets used in manufacturing or microbeads in personal care products) or secondary microplastics that result from the breakdown of larger plastics. Microplastics have a range of polymer types, sizes, shapes, and associated chemicals, with irregular shapes and fibers found increasingly in marine organisms, including mammals, fish, mollusks, and crustacea. In toxicity studies, microplastic exposures have been shown to cause adverse effects, including tissue inflammation, impaired growth, developmental anomalies, and reproductive difficulties.

In California, microplastics have been observed in Monterey Bay, San Francisco Bay, the Greater Farallones National Marine Sanctuary, Lake Tahoe, and in Southern California waterways, including preproduction plastic pellets ('nurdles') that spill from manufacturing facilities and reach California's beaches.

Microplastics are not only a marine pollution problem. Microplastics have been found nearly everywhere scientists have looked, from pristine mountain streams to agricultural soil, and within human placenta, stool samples, and lung tissue. Microplastics can enter the food web, where plastic particles can transfer into tissue, and expose humans to plastic-associated and endocrine-disrupting chemicals from seafood consumption.

In 2018, in response to rising concerns over the potential impacts of microplastics to ocean and human health in California, the California Legislature adopted Senate Bill 1422 and Senate Bill 1263, requiring the State Water Resources Control Board (SWRCB) to address microplastics in drinking water and the California Ocean Protection Council (OPC) to develop a Statewide Microplastics Strategy to address microplastics in the ambient marine environment, respectively. This Statewide Microplastics Strategy was developed in response to Senate Bill 1263 to identify early actions and outline research priorities to address microplastics in the marine environment.

To inform this Strategy, OPC collaborated with partner agencies and research institutions to enhance the scientific foundation of microplastics science. This has included the characterization of the predominant sources and pathways of microplastics in the San

Francisco Bay; initiation of standardized sampling, detecting, characterization, and microplastic monitoring methods; and creation of a preliminary risk assessment framework that provides the foundation to sample, monitor, and evaluate microplastics statewide.

The final Statewide Microplastics Strategy, developed by OPC in coordination with state agency and external partners, provides a comprehensive and coordinated approach to identify early actions California can take to address microplastic pollution and advance existing microplastic research. The recommended actions outlined in the Strategy are organized into two basic categories: management actions that California can begin implementing immediately, and research priorities to inform future actions. These two paths, taken together, reinforce and enhance each other. Immediate actions allow the state to move with the urgency this moment calls for, while future solutions are made possible only by advancing scientific knowledge.

Solutions

Microplastics are persistent and the presence of microplastics in the environment will only be magnified if microplastic pollution remains unaddressed. The diverse sources and pathways from which microplastics enter the environment requires a comprehensive and systemic approach to prevent and manage microplastic pollution. Microplastics are extremely challenging, if not impossible to effectively remove once in the aquatic environment. This Strategy therefore focuses on solutions to prevent microplastics from entering the marine environment in the first place. These solutions are grouped into three broad categories: pollution prevention, pathway intervention, and outreach and education.

Each of the recommended actions addresses microplastic pollution in California as multi-benefit, 'no regrets' actions. 'No regrets' actions are identified based on a combination of factors, including feasibility, evidence to support those actions, available co-benefits, and overall benefit to our society and environment.

Pollution Prevention

Managing and preventing plastic pollution provides an important opportunity to prevent the proliferation of microplastics that fragment from larger plastics. Microplastics are pervasive and persistent in the environment, with microplastics in the ocean anticipated to increase by almost 300 percent by 2030. In the Southern California Bight alone, trash is pervasive within watersheds and on the seafloor with the majority of trash observed from 2013 to 2018 comprised of plastic, according to Southern California Bight Regional Monitoring Program findings.

Reducing plastic production and waste has the additional benefit of supporting national and California climate goals, given greenhouse gas emissions from plastics production have quadrupled since 1995, in part due to plastic demand in the European Union and United States. Health impacts associated with the life cycle of plastics, including increased particulate matter pollution, are further recognized as a human rights issue that falls disproportionally on vulnerable communities.

Source reduction of plastics is one of the most effective precautionary strategies to reduce and prevent microplastics pollution, given the lack of feasible microplastics cleanup strategies, persistence of microplastics that enter the environment, and the need to prevent the internalization of microplastics by marine organisms. This Strategy outlines three approaches to prevent microplastic pollution: (1) product and material regulations, (2) economic strategies, and (3) identifying and advancing product alternatives.

Product and Material Regulations

Disincentivizing the production, sale, and use of plastic materials can prevent the proliferation of microplastics in the environment. California already has demonstrated its commitment to reducing plastic waste by enacting a series of product and material prohibitions and other laws aimed at reducing plastic waste. This Strategy calls on California to pursue additional product and material prohibitions to further curb the generation of plastic waste.

Despite existing programs and requirements to reduce the use of specific single-use plastic items, California has not yet enacted a comprehensive approach to reducing plastic pollution. Efforts, such as the proposed California Recycling and Plastic Pollution Act of 2022 and the Plastic Pollution Producer Responsibility Act, seek to reduce single-use plastics by setting target reduction dates and require producer responsibility to help finance waste infrastructure improvements and help restore California's ocean, rivers, and beaches. Without consistent targets or comprehensive requirements to reduce plastic pollution, California remains limited to addressing plastic pollution and waste on a single-item or single-jurisdiction basis.

Elimination of specific single-use plastic products that are not readily recyclable should be pursued as more comprehensive programs and regulations are established. As one example, a statewide prohibition of expanded polystyrene in foodware and packaging can prevent the persistence of expanded polystyrene in the environment, as it easily breaks apart, mixes with coastal sand and sediment, and is often unable to be recycled due to food contamination. Additionally, prohibiting the sale and distribution of cigarette filters, which are among the top littered plastic items globally on a per-item basis and contain damaging chemicals, and other tobacco products that contribute to microplastic pollution can reduce the presence of microplastics from tobacco products in the aquatic environment. California can additionally act on international recommendations to restrict the use of intentionally added microplastics in specific consumer products, such as cosmetics, household and industrial detergents, and cleaning products.

Economic Strategies

Economic strategies and programs by both state and federal partners can drive innovation in product design and materials, incentivize consumer habits, and improve the overall life cycle management of products that contribute to microplastic pollution. Economic strategies may include the use of taxes, fees, subsidies, consumer rebates, or extended producer responsibility (EPR) to drive innovation and improve management.

EPR can support a circular economy and assign producers responsibility for the end-use management of specific products. EPR can specifically advance solutions that recognize the entire life cycle of products, and help fund research, environmental monitoring, and waste management improvements. In California, EPR programs are in place for products such as paint, mattresses, carpet, and pesticide containers.

Financial incentives and programs can additionally target specific consumer products, such as home clothing appliances, to reduce microplastic pollution caused by textile shedding that enter the environment through clothing dryer vents or washing machines. Requirements for improved filters inside home appliances may be pursued as technology continues to advance.

Identifying and Advancing Product Alternatives

Effective pollution prevention requires specific industries and diverse stakeholders to advance innovation, identify actions to advance alternative products, and pilot plastic waste reduction solutions. This Strategy calls for advancements in technology to identify alternative products, sourcing, design, and overall plastic reduction strategies that may be voluntarily taken up by targeted industries – and influence domestic and global markets with improved products, design, or materials.

Targeted, sector-specific workshops should be held to investigate, conduct an alternative analysis, and identify sector-specific recommendations to reduce microplastic pollution from the following priority industries: (1) vehicle tires, (2) textiles, (3) single-use foodware and packaging, (4) agriculture, and (5) fisheries and aquaculture. Alternative materials and design of pre-production plastics, granules of plastic less than 5 mm in size known as 'nurdles,' should also be explored. These workshops should result in explicit sector-specific recommendations and immediate actions to enact plastic pollution prevention strategies, based on the use, cost-effectiveness, and benefit of each product and product alternative, life cycle assessments that incorporate global climate, social, and food security impacts consistent with the United Nations Sustainable Development Goals, and chemical additive safety to avoid regrettable substitutions.

Pathway Interventions

California must prioritize management solutions that intercept large plastic debris and microplastic pollution before it reaches the marine environment. Scientific studies completed in San Francisco Bay identified urban runoff as a major pathway for microplastics, with average concentration and overall load of microplastics in urban stormwater approximately two orders of magnitude higher than in treated wastewater effluent. Additional statewide studies are needed to assess whether urban stormwater runoff has similarly high contributions of microplastics in other regions of the state, and to what extent agricultural runoff and aerial deposition transport microplastics into California waters to identify additional pathway interventions.

As research advances to identify the full range of pathways by which microplastics enter the environment, California should pursue immediate pathway interventions that have multiple benefits for water quality and the overall management of California's water system.

Stormwater

In many California urban areas, rainfall washes particles into stormwater collection systems that discharge directly into receiving waters, such as California's rivers, estuaries, and ocean. Comprehensive studies of microplastics in California urban runoff outside of the San Francisco Bay area have not yet been conducted, although the relatively high microplastic concentrations measured in San Francisco Bay stormwater are generally consistent with limited observations of microplastics in stormwater in international locations. The importance and prevalence of microplastics in urban stormwater runoff observed in the San Francisco Bay should be confirmed as a predominant pathway in other urban areas in the state; however, existing studies demonstrate improved stormwater management as a viable and available management strategy to reduce the flow of microplastic pollution from municipalities into the marine environment.

Trash and marine debris, which are largely comprised of plastic, have become a policy focus throughout California, with several policies and management actions implemented to reduce the amount of trash that reach state waters. Trash capture, such as full-capture devices, can be used to interfere and remove debris from stormwater. These strategies can help prevent the flow of large plastic pollution into receiving waters and help mitigate microplastic pollution by reducing large plastic debris that can fragment into microplastics. Low impact development (LID), such as bioretention rain gardens, high-flow bioretention systems, and infiltration trenches, offers opportunities to capture both large plastic debris and microplastics and provide additional pollution reduction and groundwater augmentation benefits.

Wastewater

Wastewater is a known pathway of microplastic and microfiber pollution, whether directly through wastewater effluent or as indirect discharge through the land application of biosolids. Available data indicate that microplastic concentrations and loads from wastewater are significantly smaller than those in urban runoff in San Francisco Bay; however, comparison data for other locations in California are absent. Additional research is needed to determine the consistency of these findings in other California regions. Numerous studies demonstrate that wastewater treatment plants with only primary and secondary treatment levels release higher concentrations of microplastics than wastewater treatment plants with tertiary or advanced levels of treatment, which release negligible levels of microplastics.

While tertiary and advanced treatment have demonstrated efficacy in preventing microplastic pollution from entering receiving waters, microplastics may be applied to land and impact soils through the biosolid byproduct of wastewater treatment plants. Preventing microplastics from entering wastewater treatment systems reduces the risk of direct or indirect microplastics discharges. An all-of-the-above approach, including pollution prevention and wastewater facility upgrades, where feasible and practicable to prevent microplastics from entering the marine environment through another wastewater stream, should be taken to manage microplastics in wastewater. Advancing recycling of wastewater that would otherwise be discharged directly into the ocean and promoting tertiary wastewater treatment are examples of multi-benefit actions that can have the potential to improve coastal water quality, advance California's water recycling goals, and manage microplastic pollution.

Aerial Transport

Atmospheric transport drives the widespread distribution of microplastics in the global environment, particularly in remote regions. Microplastics have been found to be transported from distances of up to 95 km away, with road and tire wear particles known to contribute to airborne microplastics that enter urban stormwater. Aerial transport is a potentially significant pathway of microplastics into the marine environment, and further research is needed to understand the full implications of the transport, deposition, and exposure to both human and marine health from microplastics in air.

Dryers are further identified as a potentially significant source of textile fiber emissions in outdoor air. Improving lint capture technology on dryers provides an opportunity to intervene with microparticles and microfibers and prevent these particles from becoming airborne. Moving toward the capture of microfibers from dryers and encouraging use of alternatives such as hanging textiles to dry can abate one source of microplastic pollution, while research is pursued to advance understanding of emissions from this pathway.

Outreach and Education

Meaningful public engagement is a cornerstone to reducing and preventing large plastic and microplastic pollution. Public awareness, engagement, and education are an important and overarching component of this Strategy to raise awareness about microplastic pollution and facilitate public behavior, policy, systemic, and environmental change.

Public outreach and engagement play an important role in evaluating impacts of microplastic exposure and ensuring individual projects and pollution prevention strategies are informed by local community needs. California has existing requirements and commitments to implement effective government-to-government consultation with California Native American Tribes on the development of legislation, regulations, rules, and policies on matters that may affect tribal communities. Impacts of microplastic pollution on tribal ancestral lands and resources should be evaluated and considered, with individual strategies to address microplastic pollution evaluated and informed by impacted tribes. California should additionally prioritize local engagement with vulnerable populations, such as communities disproportionately burdened by environmental injustice and those historically excluded from decision-making processes, to evaluate specific strategies to reduce microplastic pollution and exposure.

Raising public awareness of microplastic pollution complements the solutions and research priorities presented in this Strategy. Education campaigns can reduce desirability, accessibility, and acceptability of plastic products, increase consumer demand for plastic alternatives or reuse, and improve understanding of microplastic impacts on human and environmental health. Developing and advancing a coordinated, strategic public awareness campaign that educates the public to understand the sources, impacts, and available solutions to reduce macro and microplastic pollution is needed to enact the recommended early actions outlined in this Strategy.

Science to Inform Future Action

This Strategy builds from recent advancements in microplastic science and details an overarching research strategy to advance proposed solutions and shape the next generation of management solutions. The research priorities outlined in this chapter call for coordinated, simultaneous investments across four main areas: (1) Collect data on levels of microplastic contamination across the state (**Monitoring**); (2) Improve understanding of critical thresholds at which aquatic life and humans are adversely impacted by various microplastic exposures (**Risk Thresholds and Assessment**); (3) Identify and prioritize future management solutions based on the predominant ways that microplastics enter California’s marine ecosystems (**Sources & Pathway Prioritization**); and (4) Develop and evaluate new mitigation strategies (**Evaluating New Solutions**).

Monitoring

Effective management of microplastics begins with understanding the extent of microplastic pollution within the state. California has the opportunity to build from existing monitoring studies, including methods developed to collect and identify microplastics from a variety of environments, comprised of surface waters, sediments, stormwater runoff and treated wastewater effluent. Previous studies have also developed and quantified the effectiveness of laboratory measurement methods for processing water, sediment, and tissue samples. Priority research to advance microplastic monitoring include: (1) transitioning previous research into standardized methods; (2) acquiring laboratory accreditation to ensure standardized monitoring methods are employed properly and to confirm that data submitted are of acceptable quality and comparable; and (3) creating a statewide monitoring network with willing partners to design, implement, and sustain long- term operations of the network.

Monitoring provides crucial information regarding how much and what types of microplastic (e.g., particle sizes, morphologies, polymer types) are in California waters and provides the foundation for tracking future changes in response to management action. Monitoring information also provides context for exposure in various environmental matrices (e.g., water, air, sediment, biological tissue) and habitats (e.g., marine, estuary, freshwater), to directly inform which areas are most contaminated and which organisms and biological communities may be at greatest risk from microplastics.

Risk Thresholds and Assessment

Microplastics are ubiquitous in the California ocean, and determining the urgency for implementing specific management action requires a risk assessment to quantify the number and type of biota that are affected now, and are likely to be affected in the future, under different management scenarios. Data availability to assess risk is increasing rapidly, which will only strengthen risk assessment outcomes in the future.

Using updated and strengthened thresholds to quantify both existing and future risks from microplastics exposure, including whether risks would change under a range of management scenarios (e.g., pathway interventions, source control, and/or no action), will help California identify the habitats and/or communities that may be most affected by plastic pollution, and provide insight as to which management actions are most needed to reduce microplastic exposure. Risk evaluations should address the probability of exposure, the magnitude, duration and frequency of exposure, and the magnitude of adverse impacts or consequences that could result from microplastic exposure to environmental and human health. Information acquired from future monitoring and reporting of microplastics in drinking water can further inform risk assessment of the potential exposure risk of microplastics for human health.

Risk evaluations for vulnerable communities, such as those underserved, historically excluded from decision-making processes, and disproportionately burdened by environmental injustice, should be prioritized, as these communities may be at greater risk from microplastic pollution due to disproportionate community exposure from a variety of possible pathways, such as inequitable distribution of plastic products, plastic manufacturing facilities, higher densities of trucks, other vehicles, and associated tire degradation particles and fibers, and emissions of plastics particles and fibers from fixed sources. Advancing and conducting risk assessments can evaluate the potential socioeconomic factors that magnify the risk of microplastic exposure and help identify future solutions to reduce the risk of exposure.

California can support comprehensive risk assessments and inform future regulatory action by: (1) identifying ambient exposure concentrations generated through the statewide monitoring program; (2) applying risk thresholds; and (3) updating risk assessment frameworks by incorporating new ambient concentration data and toxic effects data as they become available, and quantifying risk based on these new values.

Investing in and prioritizing additional research will provide California with information needed to guide future management decisions. Advancing the research priorities of this Strategy will provide actionable risk thresholds and identify future source control actions needed to inform a water quality objective and program of implementation, to ensure protection of aquatic life and beneficial uses of California waters.

Sources and Pathways Prioritization

To reduce microplastic pollution in aquatic environments, management actions must target and prioritize the predominant sources and pathways by which microplastics accumulate and pose ecological and human health risks. Sources are the original products and manufacturing processes that can trigger the generation and initial release of microplastics; meanwhile, pathways are the transport mechanisms (e.g., runoff, air) through which microplastics reach aquatic environments.

California can build on past research to assess pathways not yet fully studied (e.g., agricultural runoff, air deposition) and confirm the prominence of microplastic transport in stormwater in other regions of the state. Future research priorities may include an assessment of windborne microplastics and the quantification of macro and microplastic contributions from agriculture to the marine environment, including monitoring microplastics in agricultural soils, biosolids, and runoff.

For each pathway, particles should be characterized (according to size, morphology, polymer type) in addition to quantifying the total amount of microplastics present. Additionally, advancing source identification methods can provide insights to inform industry-specific source control measures. Research should focus on investigating sources for which viable management remediation strategies can be readily developed. Preliminary priorities include identifying solutions and strategies to reduce microplastic discharges from tire and road wear, laundry and textiles, tobacco products, and agricultural runoff. California should prioritize the development of a source emissions inventory, dependent of the availability of necessary data, to quantify the top sources that contribute to microplastics in California's marine environment and to refine and inform future management actions. A key consideration of this work should include selecting sources that may disproportionately affect marginalized or frontline communities.

Evaluating New Solutions

Once the occurrence, risks, priority sources and pathways associated with microplastics have been identified in specific localities in California, targeted solutions to mitigate microplastic contamination can be prioritized and implemented. Feasibility and efficacy studies, and future risk assessments, can inform future management actions as new innovations are identified and developed in California, nationally, and abroad. Future management actions and solutions should include life cycle assessments that incorporate global climate, social, and food security impacts, evaluations of a range of possible alternatives, including an evaluation of no action, cost-effectiveness, and chemical additive safety to avoid regrettable substitutions.

This Strategy will identify new solutions and management actions as new information and approaches become available. To implement these research priorities, evaluate the efficacy of early actions, and inform future solutions, California will collaborate with scientific experts across academic institutions, federal and state agencies, and other organizations over the next four years.

The complete California Statewide Microplastics Strategy can be found ***here****.*

News and Announcements

Renewable Natural Resources Foundation

RNRF Round Table: Natural Gas and the U.S. Energy Transition

Nikos Tsafos, James R. Schlesinger Chair in Energy and Geopolitics with the Energy Security and Climate Change Program at the Center for Strategic and International Studies (CSIS), spoke at the RNRF Washington Round Table on Public Policy on November 15, 2021. He spoke about the role of natural gas in the U.S.'s transition to a clean energy economy.

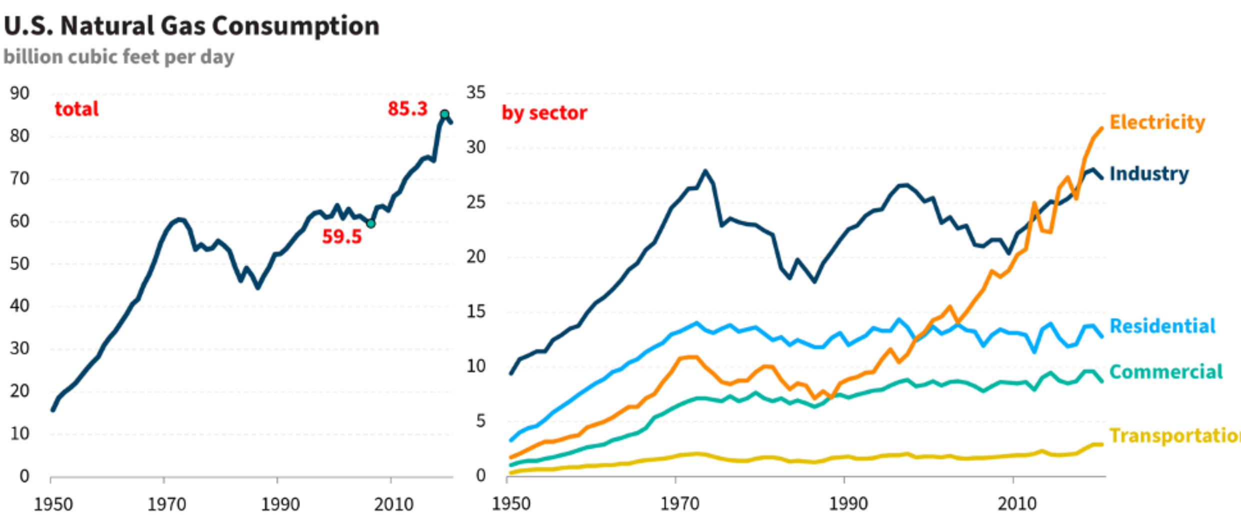
Tsafos began his presentation with two central facts about the role of natural gas in the U.S.'s energy transition. First, the United States has a large supply of natural gas which is very cheap to produce. Second, to reach net-zero emissions and accomplish its Paris Agreement goals, the U.S. will have to either eliminate gas use altogether or, at least, eliminate carbon emissions from gas. Either of these tasks will be very difficult to accomplish.

Background

Total natural gas production and consumption in the United States has risen considerably in the past fifteen years. Most of the growth in production has been the result of new innovations like horizontal drilling and hydraulic fracturing making production much cheaper. As production has increased, domestic gas prices have fallen and have become consistently lower than prices in the rest of the world. Lower prices have helped drive an accompanying rise in consumption, driven mostly by an increase in gas use for electricity generation. However, consumption in the industrial sector has also increased significantly, and residential gas use remains very stable. In this time frame, the U.S. has also become a net exporter of natural gas for the first time – it has grown to supply 20% of the global market for liquified natural gas (LNG).

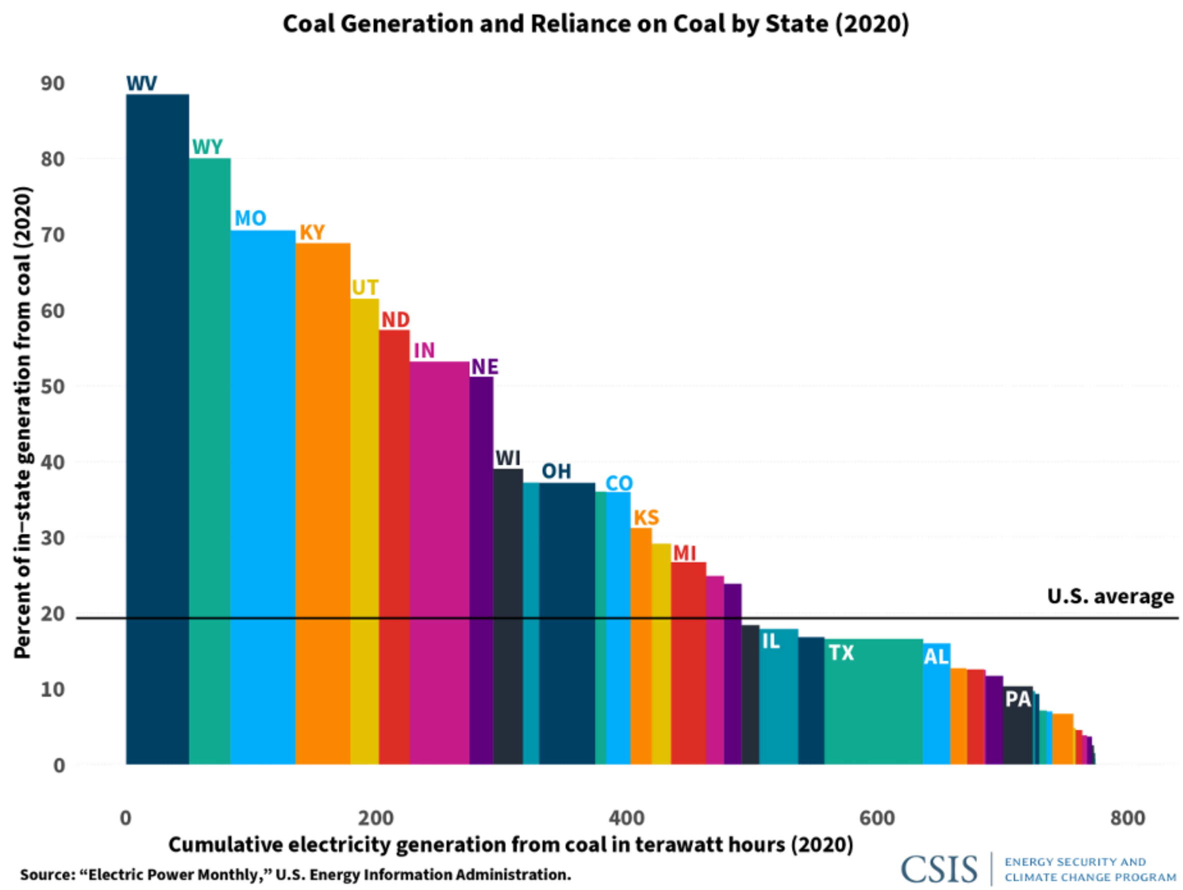
Tsafos emphasized that the future of gas is not just the future of its role in electricity generation. A common narrative about the energy transition is that, with the expansion of renewables, natural gas will soon no longer be necessary. However, renewables primarily replace gas only in electricity generation, which is only one sector where it is used. It is more difficult to replace gas with renewables in industrial, residential, and commercial applications. For this reason, it is important to talk about gas in sector-specific terms. Tsafos organized the rest of his presentation around discussions of each major sector where natural gas is currently used.

Figure 1



Source: U.S. Energy Information Administration, Table 4.3 Natural Gas Consumption by Sector, Monthly Energy Review, October 26, 2021.

Figure 2



Electricity

In the past 15 years, the U.S. has undergone a huge transformation in its electrical power sector. This has been characterized mainly by a reduction in the use of coal and an increase in the use of natural gas for electricity generation. Wind and solar capacity have also increased, but not as significantly as natural gas. About two-thirds of the reduction in coal-fired electricity generation has been replaced with gas, and the rest was replaced largely by wind and solar.

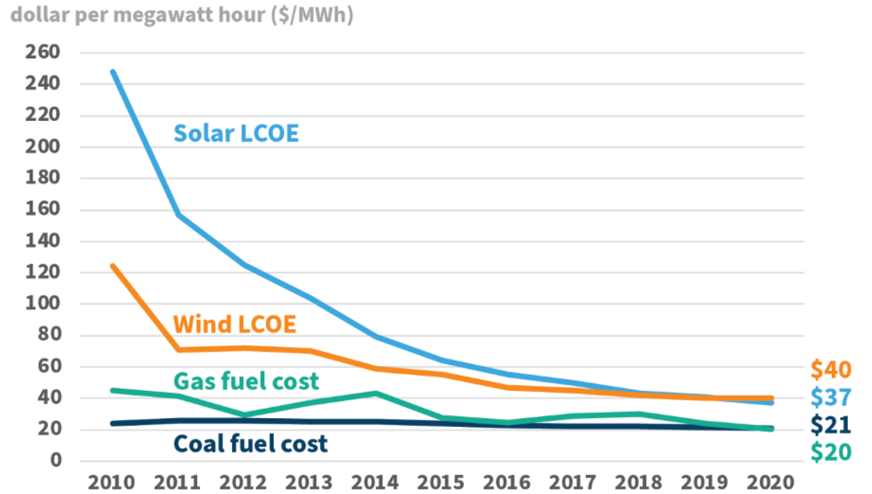
Environmentally speaking, natural gas, when burned, is superior to coal in terms of both planet-warming carbon emissions and local air pollution. The replacement of coal with natural gas in the energy system in recent years has caused significant emissions reductions. However, gas still emits carbon into the atmosphere when burned, so the reductions that can be achieved through this switch are limited. As Tsafos noted at the beginning of his presentation, to achieve net-zero carbon emissions, gas will have to either be replaced by zero-carbon alternatives or the emissions from gas will have to be eliminated. These are both difficult propositions.

The U.S. is a big country, and nationwide trends are not uniform everywhere. Even though gas and renewables have increased their share of electrical generation capacity on a national level, there are still significant variations in state-level performance. Overall, as a country, the U.S. only produces about 20% of its electricity from coal. However, coal still accounts for more than 50% of generation capacity in eight states. This is an important lesson for the future of natural gas in the U.S.: even if use of a certain energy source is waning nationally, there can still be pockets of heavy use that are difficult to dislodge.

President Biden has set a target for 80% of the U.S.'s electricity generation to be carbon-free by 2030. Tsafos walked through a hypothetical thought exercise to discern what that could mean for natural gas generation this decade. The exercise assumes that coal and petroleum generation will reach zero by 2030 and hydroelectric and nuclear capacity will remain stable. In this situation, the U.S. would have to increase solar and wind capacity by a factor of about 5 and reduce natural gas generation by about half. This would create an energy mix with 80% carbon-free generation and 20% fossil fuel-based generation (all from natural gas), in line with the president's goal. Due to its cheap price, natural gas generation has replaced coal to a very significant degree in the last 15 years. Now, to achieve climate goals, its use will have to be reduced rapidly over a short timeframe.

Figure 3

Cost to Build Solar and Wind versus Fuel Costs for Coal and Gas



Note: LCOE is levelized cost of electricity. Source: Data for wind and solar from Lazard, *Lazard's Levelized Cost of Energy Analysis: Version 14.0* (Lazard, October 2020), https://www.lazard.com/media/451419/lazards-levelized-cost-of-energy-version-140.pdf; fuel costs for coal and gas estimated based on data from the Energy Information Administration (cost of fuel times fuel consumed against total net generation from coal or gas).

CSIS | ENERGY SECURITY AND CLIMATE CHANGE PROGRAM

In order to precipitate widespread replacement of existing gas generation with renewables, the cost of building a new wind or solar generation facility must be less than the cost of running an existing gas or coal facility. Figure 3 shows the cost of gas and coal fuel compared to the levelized cost of electricity (LCOE) without subsidies for solar and wind. Because of subsidies, solar and wind installations are being constructed despite the levelized cost of new installations still being higher than coal and gas. However, without government support, new renewable installations are currently on average about twice as expensive as continuing to run existing fossil fuel installations. The key question to ask of energy legislation seeking to speed up the energy transition is: are the policy measures envisioned in legislation enough to bring the cost of new solar and wind lower than existing gas? This is a difficult challenge because gas is so cheap, but it is key to the future of the electric power sector.

Industry

In the United States, the industrial sector uses more energy than the commercial, residential, or transportation sectors, and the bulk of its energy comes from natural gas. Certain regional industries use huge amounts of energy – for instance, in 2018, the manufacturing industry in the South alone consumed about 12% of the country's energy. Half of that was solely from the chemicals industry. In any climate plan, reducing energy use and emissions from the industrial sector is essential.

More than any other source, the energy used in industry comes from gas, and gas's share of industrial energy use has increased in recent years. Moreover, the majority of equipment used in industrial applications is incapable of switching away from natural gas to another fuel source. In order to conduct a transition away from gas in the industrial sector, new equipment will be necessary in many cases.

Rather than replacing gas-burning equipment, another solution that has been proposed is the adoption of carbon capture utilization and storage (CCUS), which primarily involves capturing carbon before it enters the atmosphere and storing it underground. Currently, there is only a very low level of policy support for this technology, and it remains too expensive to be adopted at scale. Universal adoption of CCUS would require a drastic increase in policy support.

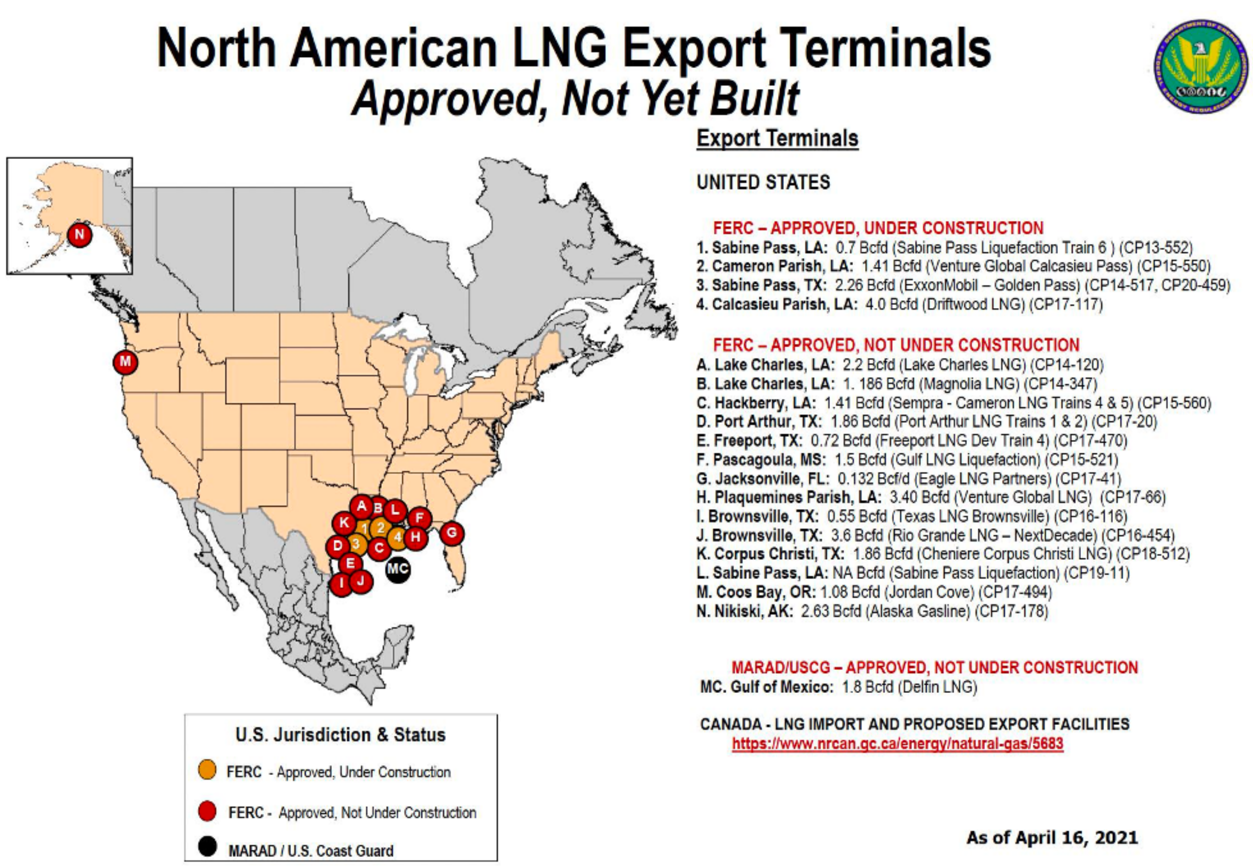
Buildings

A significant portion of the U.S.'s natural gas use is in buildings, where it is primarily used for space heating. There are multiple solutions to reduce reliance on gas in this sector. One is to improve the energy efficiency of buildings. If a building is built more efficiently, it is less prone to its heating or cooling escaping to the outdoors, and therefore will use less energy for temperature control. A widespread effort to retrofit buildings would be necessary to improve building energy efficiency on the necessary scale to meet climate goals, and thus far, the U.S. has still made very little progress in doing so.

The other aspect of building efficiency that Tsafos focused on is the equipment used for space heating. Currently, natural gas accounts for a large portion of energy use for space heating around the world. By 2050, if the world is to accomplish net-zero climate goals, natural gas-fueled space heating must be eliminated. In this scenario, gas would primarily be replaced by heat pumps, which use electricity to heat and cool a building, and these heat pumps would be powered primarily by renewable electricity.

In the U.S., heating, cooling, and ventilation accounts for more than 50% of home energy use. About half of U.S. households rely on natural gas as the primary means of heating their home. If the U.S. is to meet its climate goals, the use of gas to heat buildings will have to be phased out. The current economics of electric heating are not favorable to this happening soon. At the moment, electric heating is still much more expensive on average than heating a building with natural gas. While electric heat pumps are becoming more reliable and affordable with time, policy support will be necessary for an energy transition in the building sector to happen in the immediate future.

Figure 4



Exports

The U.S. is already a large exporter of liquified natural gas (LNG), supplying about 20% of the global market, and more export facilities are still being built and planned (Figure 4). How we think about natural gas and the energy transition in the United States is not entirely a question of domestic consumption. The U.S. also plays a significant role in the global marketplace for natural gas, meeting the consumption needs of other countries. This is an important consideration when thinking about the future of gas production in the U.S.

Methane Leakage

In the Q&A session of the round table, Tsafos addressed the issue of methane leakage from natural gas infrastructure. The role of gas in the energy transition is complicated by the fact that natural gas is primarily composed of methane, which is a greenhouse gas that contributes more to climate heating in the short-term than CO_2. Limiting methane emissions is an essential part of addressing climate change. Atmospheric concentrations of methane are rising, but our knowledge of the degree to which different sources are emitting it is limited. Scientific work is being done to determine the sources of methane emissions, so understanding of this issue will improve with time. For now, it is known that natural gas infrastructure contributes to methane leakage, but it is not known exactly how significant a source it is.

Depending on how much methane leaks into the atmosphere during the production and transportation of natural gas, its environmental benefits compared to coal can weaken or, in rare cases, even be eliminated altogether. Any case for the climate benefits of natural gas is undermined if methane leakage is not addressed. The first step in doing so is to invest in better monitoring of methane emissions. Until accurate data on the extent of the problem is available, it will be impossible to solve it effectively. Stronger regulations will also be necessary to incentivize companies to reduce their methane emissions. This is not a particularly expensive undertaking. Often, costs to mitigate leakage are recouped because less gas is being wasted. On a net basis, companies can make money back from this endeavor, but regulation is necessary to ensure that it is actually being done.

Just Transitions for the Natural Gas Sector

In the Q&A session, Tsafos also addressed the issue of just transitions for workers in the natural gas industry in the U.S. If, as he demonstrated in his presentation, natural gas capacity is reduced by 50% this decade to meet climate goals, a lot of people who work in the natural gas sector will lose their jobs. The last energy transition, from coal to natural gas, was not smooth. It occurred very abruptly and little was done to support the people and communities that were impacted by the closure of mines and power plants. It is very difficult to maintain a strong local economy when its major industry disappears. Tsafos identified two key points which can help to smooth the energy transition for communities that currently rely on the gas industry. First, he noted that environmental remediation is necessary – if the remnants of the gas industry are not cleaned up, it can be more difficult to bring other industries in. Second, he noted that the solutions for a just transition are different in different communities. Gas industry jobs lost to the energy transition do not need to be replaced by jobs working with renewables. Regionally focused efforts to find and grow successful institutions and businesses are necessary, and these efforts should be responsive to the needs of the community.

Conclusion

Natural gas will need to be phased out if the United States is to meet its net-zero targets. This will be very difficult to accomplish. In the power sector, gas faces competition, primarily from renewables, but it remains cheap and will be difficult to dislodge without policy support for renewables. In the industrial sector, a net-zero pathway will rely largely on CCUS and/or hydrogen, rather than electrification and renewables. Eliminating gas use from buildings will require a huge turnover in the appliances used, especially for space heating. At this moment, the economics of such a shift are generally still not favorable, depending on location. And, finally, the U.S. is still conducting a huge push to export gas to the rest of the world. The U.S.'s domestic ambitions to reduce gas use must be reconciled with the fact that a lot of other countries are expecting to rely on U.S. gas for their own energy.

– Stephen Yaeger, RNRF Program Manager

To view the PowerPoint associated with Tsafos's presentation, click **here**.

American Geophysical Union

Recent AGU publications updates help authors and expand open access

We are pleased to share an update on our ongoing efforts to make it more rewarding to publish your research with AGU.

A critical part of AGU's mission is making science available to the widest possible audience and exemplifying an inclusive scientific culture. Our strategic plan guides us in balancing the long-term sustainability of our journals with equity of access and inclusion for all in our community.

In case you missed it, we recently announced that AGU members now have access to the full text of all AGU subscription journals, amounting to thousands of cutting-edge papers each year spanning the Earth and space sciences. This is not only a significant value for AGU members, but also another step in our commitment to expand access to content, with the support of our publishing partner, Wiley.

To read more, click **here**.

American Meteorological Society

American Meteorological Society Policy Program Publishes Two New Climate Studies

The American Meteorological Society's Policy Program uses the society's scientific expertise to help the nation, and the world, avoid risks and realize opportunities associated with the Earth system. Recently, the program published two new studies about climate issues, covering topics related to the impacts of data and technology on the weather, water, and climate (WWC) enterprise, and socioeconomic inequality and climate change in the Great Lakes region.

In an effort to better understand workforce challenges and opportunities in the WWC enterprise, the AMS Policy Program released "Who Will Make Sense of All the Data? Assessing the Impacts of Technology on the Weather, Water, and Climate Workforce" in October of 2021. This study explores the state of the technological landscape in WWC science and its implications for employers and employees across the public, private, and academic sectors. Synthesizing the perspectives of experts throughout the WWC enterprise, along with additional analysis, they detail the opportunities and challenges for workforce adaptation that are required as a result of technological advancement. Additionally, they discuss frameworks to support the current and future workforce across all career levels within the enterprise. The study can be found **here**.

"Socioeconomic Inequality and Climate Change Hazards: A Focus on the Great Lakes Region" was released by the AMS Policy Program in September of 2021. The report addresses two core issues that are reaching an inflection point in society: growing climate hazards and socioeconomic injustice and inequality. These issues are closely interrelated due to the increased vulnerability to climate hazards endured by people who are experiencing socioeconomic vulnerability. This report reviews this relationship, focusing specifically on the Great Lakes region. It examines the region's climate and socioeconomic risks separately, as well as the interactions between them. The report also informed a two-part workshop on the topic that gathered participants from academic, public, NGO, and other sectors with ties to the Great Lakes Region. The study can be found **here**.

American Society of Civil Engineers

Impacts of Future Weather and Climate Extremes on United States Infrastructure: Assessing and Prioritizing Adaptation Actions

Prepared by the Task Committee on Future Weather and Climate Extremes of the Committee on Adaptation to a Changing Climate of ASCE

Impacts of Future Weather and Climate Extremes on United States Infrastructure: Assessing and Prioritizing Adaptation Actions summarizes the likely changes in various extreme meteorological and hydrological events and assesses the vulnerabilities of infrastructure within critical sectors and their collective interdependencies. In addition, frameworks that decision makers can use to prioritize limited budgetary resources for adaptation efforts are reviewed.

Critical sectors are aggregated into five overarching infrastructure sectors: energy; transportation, including roads, bridges, rail, transit, and aviation; drinking water and wastewater; water storage and flood protection; and navigation, including ports and harbors. Each sector is reviewed with respect to the potential impacts of climate change pertinent to that sector, current sector fragility or resilience to such impacts, adaptation readiness, and dependency on or contribution to other sectors.

For more information, click **here**.

American Society of Landscape Architects Fund

Designing with Carbon

As the impacts of the climate crisis become more widespread, landscape architects are increasingly planning and designing landscapes with carbon in mind. At the ASLA 2021 Conference on Landscape Architecture in Nashville, landscape architects offered new approaches and tools for sequestering both operational and embodied greenhouse emissions in their projects and reaching a climate positive state faster.

According to Pamela Conrad, ASLA, founder of **Climate Positive Design** and principal at CMG Landscape Architecture in San Francisco, approximately 75 percent of all emissions are from the urban built environment, with 40 percent from buildings and 35 percent from transportation and landscapes.

To encourage landscape architects to sequester more carbon than they emit through their projects, Conrad founded Climate Positive Design two years ago. The original goal of the effort was to achieve one gigaton of carbon sequestration across all landscape architecture projects by 2050; now that goal has moved up to 2040.

To read more, click **here**.

American Water Resources Association

AWRA 2022 Spring Conference: Water Risk Under a Rapidly Changing World - Evaluation & Adaptation

April 24-27, 2022

Tuscaloosa, AL

AWRA's 2022 Spring Specialty Conference is being co-hosted by the AWRA Future Risk Committee and the Alabama Water Institute. With a theme of "Water Risk Under a Rapidly Changing World: Evaluation and Adaptation," this conference seeks to bring together a diverse multi-disciplinary group of water professionals - both thought leaders and on-the-ground implementers to disseminate, share and learn about cutting-edge solutions aimed at evaluating future water risks and improving human adaptation to those risks.

For more information, click **here**.

Geological Society of America

GSA Connects 2022

October 9-12, 2022, Denver, Colorado and virtual

GSA Connects 2022 will be hosted in Denver, Colorado, USA, from 9–12 October. Start planning ahead for space requests, and prepare to submit an abstract later this spring.

For more information, click **here**.

Society of Environmental Toxicology and Chemistry

SETAC North America 43rd Annual Meeting

November 13-17, 2022, Pittsburgh, PA and virtual

We are excited to welcome our participants for the first in-person SETAC North America annual meeting since 2019! We want to make this experience as welcoming and inclusive as possible, with the health and safety of meeting participants being our utmost concern.

Onsite participants will be able to benefit from five days packed with presentations, plenaries, topical mixers, exhibitor and networking events. Onsite participants will also enjoy our welcome reception and closing.

All on-site participants will have to follow the latest COVID policies and guidelines. Please visit our COVID policies and FAQ page for more information.

For people who cannot come to the meeting, we will have an online component where plenaries, presentations and more will be available virtually.

For more information, click **here**.

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