

Annual Report 2022



LSU | Center for Energy Studies

Center for Energy Studies Annual Report 2022

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David E. Dismukes, Executive Director | lsu.edu/ces

Research Highlights

Center Releases 2023 Gulf Coast Energy Outlook

On November 16, 2022, the LSU Center for Energy Studies released the 2023 edition of the Gulf Coast Energy Outlook (GCEO). As in previous years, this sixth edition of the GCEO provides a comprehensive overview of the Gulf Coast region's energy industry outlook for the upcoming year. David E. Dismukes, executive director and professor, and Greg Upton, associate professor, LSU Center for Energy Studies, authored the report.

The previous year's GCEO addressed post-pandemic operational adjustments implemented by industry, as well as impacts of the 2020 and 2021 hurricane seasons. The 2023 GCEO addresses implications of the Russo-Ukrainian war on global energy markets and energy security. The impacts of decarbonization policies and the Inflation Reduction Act on corporate strategies are also considered.

Findings include

- ▶ Long-run energy demand growth will lead to increased U.S. energy exports; however, a global recession would reduce demand for energy products.
- ▶ An ongoing Russo-Ukrainian conflict will force global energy supply adjustments. Crude oil prices will gradually attenuate over the next several years, while Gulf Coast natural gas prices will likely remain elevated (relative to post-2008 historic trends) due to LNG export pressures.
- ▶ Supply chain constraints—caused by the economic recovery from COVID-19, sanctions resulting from the war in Ukraine, and continued Trump-era trade policies with China—will continue for the next year.



- ▶ Decarbonization policies will challenge existing Gulf Coast energy manufacturing but also create opportunities for the region to take the lead in developing low- and net-zero emissions products. Over the forecast horizon, the GCEO sees decarbonization creating considerable regional capital investment opportunities.
- ▶ Drilling activity will continue to increase but is unlikely to return to pre-pandemic levels. Oil production is expected to reach pre-pandemic levels over the forecast horizon, a sign of continued efficiency improvements.
- ▶ Both oil and natural gas prices are anticipated to fall over the coming year. While long-run oil prices are anticipated to converge back to pre-Russo-Ukrainian war levels, natural gas prices will likely settle at average levels higher than those seen over the past decade.
- ▶ Both oil and natural gas production in the region are anticipated to experience a decade of growth despite the fact that oil and natural gas prices are both in backwardation, (i.e. expected to decline over the forecast horizon).
- ▶ Significant investment in crude oil pipelines is likely not needed at this time due to the investment in pipeline infrastructure over the past decade.
- ▶ While solar capacity will likely experience significant growth over the next five or so years, it is anticipated to be a small share of total electricity generated for the foreseeable future.
- ▶ As much as \$175.4 billion in new energy manufacturing investment activity will occur through 2030, representing a \$15 billion, or 7.9 percent, reduction in total regional capital investment relative to last year's GCEO over a comparable period of time.
- ▶ Production in the refining industry has rebounded to pre-pandemic levels and is anticipated to continue into the future, although downward revisions may be needed if a serious global economic contraction arises in the upcoming year.
- ▶ By the second quarter of 2023, Louisiana is expected to gain about 3,500 jobs. Texas is forecasted to gain about 12,200 upstream jobs between August 2022 and the second quarter of 2023; however, these model results are not anticipating employment in either state to reach pre-COVID levels over the forecast horizon.



The 2023 GCEO was made possible with sponsorship from Phillips 66, Entergy, Koch, Louisiana Oil and Gas Association, Placid, Louisiana Department of Natural Resources, Enverus, Louisiana Economic Development, Postlethwaite & Netterville, Southwestern Electric Power Company, TJC Group, LLOG, LLOX, and Southwest Insulation Contractors Association.

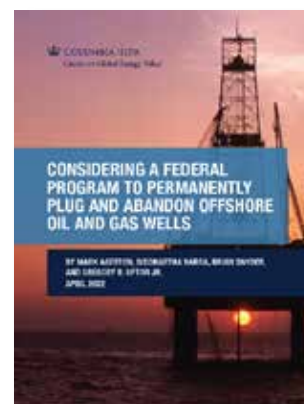
Report Provides Policy Makers Guidance on Plugging and Abandoning Offshore Wells

Center for Energy Studies faculty collaborated on a paper that examines offshore well plugging and abandoning (P&A) liabilities and provides guidance to federal policy makers during the formulation of P&A programs. Part of an oil and gas research initiative at Columbia University's Center on Global Energy Policy, the study identifies at least three objectives of potential P&A programs: reducing future financial P&A liability for tax payers, lowering environmental risk, and preserving or increasing employment while reducing greenhouse gas emissions.

The report's authors are Mark Agerton, assistant professor, University of California-Davis Department of Agricultural and Resource Economics and nonresident scholar, Center for Energy Studies, Rice University's Baker Institute for Public Policy; Siddhartha Narra, research associate, LSU Center for Energy Studies; Brian Snyder, associate professor, LSU Department of Environmental Sciences; and Greg Upton, (corresponding author), associate professor - research, LSU Center for Energy Studies.

Findings include:

- ▶ As of the end of 2020, approximately 22,000 offshore oil and gas wells in the United States were not permanently P&Aed. The cost to P&A all of these wells is estimated at approximately \$47 billion.
- ▶ Studies show that, because leaks from wells in shallow water and closer to shore pose greater environmental risks than those from wells farther offshore, and because P&Aing deeper-water wells more expensive, the cost/benefit ratio of P&Aing wells nearer to shore is more favorable than that for offshore wells.
- ▶ P&A costs associated with certain inactive wells in shallow waters that are not likely to resume production is estimated at \$8.3 billion.
- ▶ Over a 10-year period, approximately 10,500 jobs per year could be created through a P&A program for shallow-water wells.
- ▶ Oil and gas production is not expected to be impacted because the wells that would likely be P&Aed no longer produce significant quantities of hydrocarbons.



Sponsored Research

Throughout the past year, CES faculty have been involved in **28 funded LSU research projects** totaling more than **\$37.5 million dollars**. Research topics have included estimating methane emissions from orphaned and idle oil and gas wells in Louisiana, carbon storage in the offshore Gulf of Mexico, and economic impacts of certain solar and offshore wind projects.

Publications

Dismukes, David E. and Gregory B. Upton. 2023 Gulf Coast Energy Outlook. LSU Center for Energy Studies. LSU White Paper. Fall 2022.

Iledare, Omowumi O. (with E. Nsenkyire, J. Nunco, and J. Sbeu). Household multidimensional energy poverty: Impact on health, education, and cognitive skills of children in Ghana. Child Indicators Research. October 2022.

Iledare, Omowumi O. (with K. Gbakon, J. Ajienska, and J. Gogo). Oil production forecasting models and oil end-use optimization framework under global energy transition dynamics. Paper presented at the SPE Nigeria Annual International Conference and Exhibition, August 1-3, 2022. Lagos, Nigeria. SPE# SPE-211967-MS.

Iledare, Omowumi O. (with V.C. Ihejirika and B. Adeogun). Economic analysis of gas to power project in Nigeria. Paper presented at the SPE Offshore Technology Conference, May 2-5, 2022. Houston. SPE# OTC-31944-MS.

Kaiser, Mark J. BSEE decommissioning cost estimates in the deepwater U.S. Gulf of Mexico. Ships and Offshore Structures. December 2022.

Kaiser, Mark J. BSEE decommissioning cost estimates in the shallow water U.S. Gulf of Mexico. Ships and Offshore Structures. October 2022.

Kaiser Mark J. Gulf of Mexico shallow water decommissioning: Part 1. Market size. Oil, Gas & Energy Quarterly 71(1):51-58.

Kaiser, Mark J. New research illuminates P&A cost trends in the shallow-water GOM: For completed wells, average cost ranges from \$500,000 to \$900,000/well. Offshore 82(6):29-32.

Kaiser, Mark J. Shallow-water Gulf of Mexico decommissioning market valued at \$6.3 billion: Well abandonment accounts for some \$3.4 billion. Offshore 82(4):46-47.

Kaiser, Mark J. (with E.W. McAllister). Pipeline rules of thumb handbook: A manual of quick, accurate solutions to everyday pipeline engineering problems. Cambridge (MA): Gulf Professional Publishing. 906 pp.

Nehiba, Cody. Correcting heterogeneous externalities: Evidence from local fuel taxes. Journal of the Association of Environmental and Resource Economists 9(3):495-529.

Nehiba, Cody. Improving efficiency and equity with geographically targeted gasoline taxes. Transfers Magazine 9. June 2022.

Upton, Gregory B. (with M.E. Oliver). Are energy endowed countries responsible for conditional convergence? The Energy Journal 43(3):201-224.

Upton, Gregory B., Siddhartha Narra, and Brian Snyder (with M. Agerton). Considering federal program to permanently plug & abandon offshore oil and gas wells. Report prepared for Center on Global Energy Policy at Columbia University SIPA. April 2022.

Speaking Engagements

David E. Dismukes

“Louisiana industrial decarbonization opportunities.” LSU Law School, Journal of Energy Law and Resources Symposium on Energy Transitions. Baton Rouge. February 4.

Panelist. “Grid resiliency in the era of extreme weather.” Gulf Coast Power Association 8th Annual MISO/SPP Regional Meeting. New Orleans. February 9.

“Natural gas outlook, 2022: Supply, demand, and geopolitical considerations.” National Association of State Utility Consumer Advocates (NASUCA) Monthly Natural Gas Committee Webinar. March 30.

“Louisiana industrial decarbonization opportunities.” Louisiana Chemical Association/Louisiana Chemical Industry Alliance Legislative Meeting. Baton Rouge. May 11.

“Identifying and mapping regulatory requirements for CCUS projects.” SECARB Offshore GoM Gulf Regulator Workshop. New Orleans. May 16.

Cody Nehiba

“The time-of-day travel demand elasticity paradox.” Allied Social Sciences Association Annual Meeting. Virtual. January 8.

“Measuring electric vehicle mileage and response to electricity prices.” Association of Environmental and Resource Economists Summer Conference. June 3.

“Highways and pedestrian deaths in US neighborhoods.” 16th North American Meeting of the Urban Economics Association. October 1.

“Electric vehicle usage, pollution damages, and the electricity price elasticity of driving.” Southern Economic Association 92nd Annual Meeting. November 19.

Greg Upton

Economic Outlook Summit. The Advocate Webinar. January 6.

“Gulf Coast Energy Outlook.” Baton Rouge Geological Society. Baton Rouge. January 14

“Gulf Coast Energy Outlook” Southeastern Construction Owners & Associates Roundtable. Point Clear, Al. February 1.

“Gulf Coast Energy Outlook.” Louisiana Government Finance Officers Association (GFOA) 2022 Winter Workshop. Baton Rouge. February 22.

“Gulf Coast Energy Outlook.” National Oil Recyclers Association (NORA). San Antonio, Tx. March 1.

“Gulf Coast Energy Outlook.” Electrical Equipment Representatives Association (EERA). New Orleans. March 29.

“Gulf Coast Energy Outlook.” Southwest Insulation Contractor’s Association. New Orleans. June 6.

“Gulf Coast Energy Outlook.” Louisiana Gas Association Conference. New Orleans. July 20.

“Gulf Coast Energy Outlook.” Metals Service Center Institute (MSCI). Chicago, Il. September 30.

“Gulf Coast Energy Outlook.” United States Association for Energy Economics (USAEE). Houston, Tx. October 25.

“Gulf Coast Energy Outlook.” International Association of Drilling Contractors (IADC). New Orleans. November 3.

“Gulf Coast Energy Outlook.” Bayou Blue Middle School Robotics Club. Webinar. November 7.

“Gulf Coast Energy Outlook 2023 Kickoff Event.” Webinar. November 16.

“Gulf Coast Energy Outlook.” West Iberville Community Advisory Panel. Plaquemine, La. November 22.

Presentation to Louisiana Legislature State Tax Structure Subcommittee of the House Committee on Ways & Means. Baton Rouge. November 30.

Presentation to Louisiana Public Service Commission, Docket No. R-35462. Baton Rouge. December 15

Faculty Highlights

LSU President Interviews Dismukes for Podcast

Executive Director and Professor David Dismukes appeared on the June 30 episode of On Par with the President, a podcast hosted by Louisiana State University President William F. Tate IV. In this segment, Dismukes discusses gasoline prices, energy, the global impact of Louisiana's energy industry, and more.

The On Par podcast features LSU students, faculty, or staff who are at the very top of their game about their journey to success, setting and fulfilling goals, creating a legacy, and a variety of other topics.



Upton, Nehiba Provide Comment on EPA's Proposed RFS Small Refinery Exemption Decision

In December 2021, the U.S. Environmental Protection Agency (EPA) proposed to deny more than 60 pending small refinery exemption (SRE) petitions from small refineries that were requesting an exemption from the Renewable Fuel Standard (RFS) program. The RFS is a federal program that requires transportation fuel sold in the United States to contain a minimum amount of renewable fuels, such as ethanol, blended into the fuel purchased by consumers.



Center for Energy Studies Associate Professor-Research Greg Upton and Assistant Professor-Research Cody Nehiba, on behalf of the Perkins Coie Law Firm, LLP, provided an opinion on two specific claims made by the EPA in its proposal. Their expert opinion was submitted to the EPA in Docket No. EPA-HQ-OAR-2021-0566.

Perkins Coie LLP, 20 small refineries with diverse geographic dispersion, and three anonymous academic reviewers were given the opportunity to review and provide feedback on the report.

The report is available for download at https://www.lsu.edu/ces/research/sre_upton_nehiba_2022.php

Energy Supply Chain Class Tours Facilities

As part of his Spring 2022 Energy Supply Chain MBA course, CES Associate Professor Greg Upton had students visit several energy sites in South Louisiana for an up-close, real-world learning experience. Sites included

- ▶ Cameron LNG's Farid Bogani Technology Center in Hackberry, La.;
- ▶ UL-Lafayette's Photovoltaic Applied Research and Testing (PART) Lab;



Students in Upton's MBA Energy Supply Chain course visit UL-Lafayette's Photovoltaic Applied Research and Testing (PART) Lab, a 1.1 megawatt research facility that tests several types of solar modules.

- ▶ the LSU co-gen plant, which serves more than 350 buildings with 20 MW of electrical generating capacity, 21,500 tons of cooling, and 250,000 pounds per hour of 150 pound steam;
- ▶ and Entergy's J. Wayne Leonard Power Station, a 980-megawatt combined-cycle, natural-gas-fired power plant, anticipated to save customers approximately \$1.3 billion over its anticipated 30-year life.

Nehiba Named AERE Scholar

In June, the Association of Environmental and Resource Economists (AERE) accepted CES Assistant Professor Cody Nehiba into its Scholars Program, a mentoring initiative focused on increasing diversity in the fields of environmental and natural resource economics. The program is open to early-career scholars in environmental or natural resource economics who are no more than five years post Ph.D. Scholars receive \$1,500 per year for travel to the AERE Summer Conference for the two years beginning and ending the program. In its announcement of Nehiba's acceptance, the AERE commended his research focus on "market failures and negative externalities in the transportation sector, with an emphasis on producing equitable and efficient policy recommendations."



Events & Outreach

IAEE Webinars Address Decarbonization, Natural Gas Flaring

In January, Greg Upton and Mark Agerton, assistant professor of agricultural and resource economics at the University of California, Davis, organized and moderated an International Associate for Energy Economics (IAEE) virtual panel discussion for the 2022 Allied Social Science Associations annual meeting. The focus of the talk was the economics and politics of decarbonization. Panelists were Robert Stavins, A. J. Meyer Professor of Energy & Economic Development, Harvard Kennedy School; Barry Rabe, J. Ira and Nicki Harris Family Professor of Public Policy at the Ford School, University of Michigan; Adam Sieminski, senior advisor at the King Abdullah Petroleum Studies & Research Center; and Louisiana Congressman Garret Graves.

In July, an IAEE webinar titled "Quantifying the Role of Midstream Congestion and Market Structure in Permian Flaring" featured Upton, Agerton, Wesley Blundell of Washington State University, and Ben Gilbert of the Colorado School of Mines. The webinar addressed the role of constraints in the supply chain of natural gas production on flaring. The team used a novel dataset on shale development activity in West Texas' Permian Basin to estimate the causal impact of limited transmission pipeline capacity on flaring. They also estimated short-run relationships between variation in natural gas processing capacity and gathering line density on flaring. And, they considered the potential substitution between flaring and methane leakage in the supply chain for natural gas.

Upton Participates in Advocate's Economic Summit

On Jan. 6, Greg Upton participated in a panel discussion at the virtual Economic Outlook Summit presented by The Advocate. He provided the outlook for upstream and downstream oil and gas and petrochemical sectors. When asked about offshore wind, Upton noted that technological advancements would be required for increased development in our region. Asked to discuss decarbonization efforts and their impacts on Louisi-

ana's energy and petrochemical companies, Upton noted that those efforts had the potential to serve as major economic drivers in the region, citing a recent clean energy investment by Air Products in Ascension Parish.

Panelists included Adam Knapp, CEO of the Baton Rouge Area Chamber; LelaMae Wilkes, CEO of Brown Eagle; William Campbell, Jr., director of the b1 Bank Foundation; Dr. Catherine O'Neal, chief medical officer at Our Lady of the Lake Regional Medical Center; and Jonathan Walker, senior commercial sales and leasing executive, Maestri-Murrell.



CES, LMOGA Workshop Addresses La. Energy Climate Solutions

On June 21, the Center for Energy Studies, Louisiana Mid-Continent Oil and Gas Association (LMOGA), and the Consumer Energy Alliance hosted the Louisiana Energy Climate Solutions Workshop. The event featured a series of panel discussions and presentations addressing Louisiana energy, anchored to pillars of the Louisiana climate plan—carbon capture, utilization, and storage (CCUS), hydrogen, solar, and offshore wind—with an emphasis on infrastructure, investment, and incentives to promote economic growth in energy transition.

The event began with a presentation by Mike Sumrow of GHD Energy Services on CCUS principles, in which he stressed that CCUS is critical to the energy transition and that it will be necessary to meet the goals of the U.N. Climate Change Conference in Glasgow (COP26). He notes that offshore CCUS is not new and that the Gulf of Mexico has a great deal of capacity for CO2 sequestration. Legal challenges to decarbonization efforts were discussed by Bryant Bremer, Partner, Kean Miller, who noted that common arguments against CCS include its expense, risks for safe storage, whether it would be effective against climate change at this late stage, and doubts regarding CCS advancing the elimination of fossil fuel usage.

The event also included a panel discussion on hydrogen, considered a leading clean energy source due to its ability to be produced with low- to no-carbon emissions, emit zero CO₂ emissions at consumption, provide long-term storage of renewable energy, and serve as an energy transport medium. Panelists were Russell Richardson, Sr. Vice President, Business Development, Baton Rouge Area Chamber, Jonathan Flynn, CF Industries, and Mike Sumrow, GHD.

A featured presenter was Dr. Emily Grubert, Deputy Assistant Secretary for the Office of Carbon Management, U.S. Department of Energy, who discussed DOE's current goals: 50 percent emissions reduction by 2030; CO₂ emissions-free power sector by 2035; and net zero emissions economy by no later than 2050. In its effort to minimize environmental and climate impacts of fossil fuels from extraction to use, DOE has identified seven priority technology areas: point source carbon capture; CO₂ removal; CO₂ conversion into products; reliable CO₂ storage; hydrogen production; critical mineral production from industrial and mining waste; and methane mitigation.



Walt Musial, Principal Engineer, NREL, and Representative Joe Orgeron, Louisiana House of Representatives, discussed offshore wind opportunities in the Gulf of Mexico. Musial noted the advantages of and challenges to development. Advantages include the shallow U.S. waters, which allow for lower substructure costs, the proximity to oil and gas infrastructure, and the warmer waters and lower sea states that can serve to decrease operating costs and allow for easier turbine access. Challenges include hurricane risks, low average wind speeds, and soft soil, which limits substructure options and can increase costs. Orgeron discussed a bill filed during the 2022 legislative session that allows offshore wind leasing in state waters, or up to three miles off the shore. The bill extends limits on oil and gas leases to up to 25,000 acres to provide room for large wind turbines and allow the state space for pilot projects in state waters. In June, the governor signed the bill, which also gives the state a share of profits generated by wind farms.

The final session of the day addressed developments in solar energy. The panel featured Justin St. Marie, Senior Manager, Origination, Invenergy, and Chelsea Howard, Executive Director, Renewable Origination, NextEra, and was moderated by Randy Young, Partner, Kean Miller. Topics included how increased gas, power, and renewable energy credit prices are expected to support customer demand for renewables, even with higher near-term input costs; solar companies' goals for Real Zero carbon emissions; Florida Power and Light's efforts in decarbonization; and commercial structures in corporate renewable procurement.



In March, Associate Professor Greg Upton gave a presentation on the Gulf Coast Energy Outlook at a meeting of the Electrical Equipment Representatives Association (EERA), a professional organization of representatives from companies that provide products and services to the electric utility industry.

CES in the News



In 2022, Center for Energy Studies faculty were quoted or interviewed more than 100 times in local, regional, national, and international news outlets. Their commentary covered timely issues, including oil prices and the Ukraine invasion, developments in the liquefied natural gas sector, renewables in Louisiana, carbon capture, offshore wind, the impact of the Inflation Reduction Act on the Gulf Coast power sector, and more.

Scholarships Awarded

The Center for Energy Studies awarded two scholarships for the 2022-2023 academic year to LSU students pursuing energy-related fields of study and careers.



LMOGA/Brooksher Scholarship

Dana Lochary, a junior majoring in petroleum engineering, from Baltimore, MD.

F. Malcolm Hood Scholarship

Alexis Nibert, a senior majoring in petroleum engineering, from Johnstown, PA.



The Center congratulates our scholarship recipients and wishes them well as they continue their studies.

Personnel

Administration

David E. Dismukes, Ph.D., executive director, director of the Policy Analysis Division, and professor

Diana Reynolds, assistant to the executive director

Marybeth Pinsonneault, communications manager

Division of Policy Analysis

Gregory B. Upton, Jr., Ph.D., associate professor

Mike McDaniel, Ph.D., professional-in-residence (retired)

Don Goddard, Ph.D., associate professor (retired)

Cody S. Nehiba, Ph.D., assistant professor

Division of Research & Development

Mark J. Kaiser, Ph.D., director of the Research & Development Division and professor

Siddhartha Narra, Ph.D., research associate

Division of Energy Information & Data

Omowumi (Wumi) Iledare, Ph.D., Professor Emeritus, director of the CES Energy Information and Data Division, professor of petroleum economics and policy research, adjunct professor of petroleum economics at the Craft & Hawkins Department of Petroleum Engineering at LSU, and director of the Emerald Energy Institute, University of Port Harcourt, Nigeria.

Ric Pincomb, research associate

Stacy Retherford, computer analyst

Mike Surman, IT adviser



Minerals Processing Research Division

Ralph Pike, Director | F. Carl Knopf, Co-Director | lsu.edu/mpri

The Minerals Processing Research Division (MPRD) of the Center for Energy Studies was established in 1979 by federal legislation as one of 31 State Mineral Institutes associated with the U.S. Department of Interior. The mission includes facilitating research and public service programs in process research and technology transfer, sustainable development, energy management, and inherently safer design. This minerals processing research and public service complements and benefits from the energy research and geological research performed by the Center for Energy Studies and the Louisiana Geological Survey.

Research & Activities

The MPRD has continued its research on industrial energy conservation, which includes data reconciliation, heat exchanger network synthesis, and the utilization of captured carbon dioxide to produce value-added chemicals. We have been retooling our existing software to better evaluate opportunities in vapor recompression, which has become a reliable technology.

Collaborative research with the LSU Cain Department of Chemical Engineering has focused on catalytic depolymerization and upcycling of mixed plastic wastes for sustainable plastics recycling.

New research is being conducted to evaluate coastal marshes, which are an important carbon sink, removing carbon dioxide from the atmosphere and converting it to plant biomass. The coastal marshes of Louisiana cover approximately 10,700 square miles and comprise approximately 12 percent of the nation's coastal wetlands. A regional analysis is being used in the evaluation of the effects of new industries and existing industries on the economic structure of the region.

Industrial Energy Conservation / Energy Integration

The MPRD has been a leader in providing energy integration short courses as well as actual plant studies. Two programs that can give immediate and substantial energy savings for chemical plants and refineries are

"pinch technology" and "on-line optimization." Large companies have corporate-level groups that routinely apply pinch technology and on-line optimization. Small-to-medium-sized chemical companies in Louisiana do not have the trained personnel needed to apply this technology. These short courses have been taught to local sections of the American Institute of Chemical Engineers—about 200 chemical engineers—at more than a dozen locations across the state. These two short courses on these topics are available by request by contacting the Division at www.mpri.lsu.edu.

Pinch Technology

Energy integration (or pinch technology as it often called) involved determining the minimum energy requirements for an existing plant (chemical, food, etc.) and then determining options for reaching these goals. The first step in an existing plant was data extraction from process streams, which included the pressure, temperature, and flowrates of streams needing heating and cooling. Data reconciliation was then required to make sure the stream material and energy balances were closing. The analysis of all the process stream in the plant (or even part of the plant) allowed target utility loads to be determined, and then cost-effective process changes to meet these targets could be evaluated. Energy integration was well established technology by 2000, but the literature still saw hundreds of articles and several books being published each year.

In the early 2000s industry followed some general rules that included energy exchange matches between process streams or process stream and their utilities not being brought closer than ~200 in a heat exchanger. In the early 2000s, reducing the approach temperature to far below 200 was not effective as the cost of the heat exchanger (based on its required area) would be too high compared to the cost of the required utilities. In addition, many potential energy saving opportunities, including vapor recompression (industrial heat-pumps), were identified but dismissed because of reliability issues.

Today's industrial heat exchanger approaches temperatures of 100 and are cost effective because of improved technology. These lower approach temperatures reduce the utility loads (steam and cooling water) required in a process. In addition, vapor recompression has become a reliable technology. The MPRD is currently retooling its existing software to better evaluate vapor recompression opportunities.

Catalytic Role of Induction Heating in Sustainable Plastics Recycling

Plastics are ubiquitous, as evidenced by the formation of a terrestrial/marine plastic layer. Since the 1950s, plastic production has increased by ~6 million metric tons (MMt) annually, generating 110 MMt annually (~75 lbs of plastic per person per year),¹ with >5 MMt of ethylene, styrene, and propylene monomers produced within 25 miles of LSU. Of all plastics produced, only 7 percent have been recycled to date with the remaining waste discarded or incinerated. Production is expected to increase such that it consumes 20 percent of the global oil supply by 2050.² Additionally, it is expected to claim 15 percent of the annual greenhouse gas allotments necessary to limit the 1.5°C global temperature increase.² Current waste plastic management by incineration or pyrolysis impacts climate change and causes health problems. Existing lifecycle analyses (LCA) for reprocessing assume existing technologies, specifically pyrolysis followed by steam or high-pressure hydrocracking, both of which are energy-intensive, economically unviable and identified by the Department of Energy as "insufficient to address the growing accumulation" of plastic waste.³ To offset these CO₂-emitting processes, carbon capture, and biochar separation will be necessary, likely impacting overall process economic viability.

Recently, there have been significant efforts to break down and upcycle plastic wastes, primarily via hydrogenolysis, producing saturated linear fuel-lubricant hydrocarbons or polyaromatics, over multiple days reaction times.⁴⁻⁷ Alternative depolymerization routes, such as induction heating, are environmentally friendly (i.e., minimize CO₂ generation) and increase the rate of depolymerization.⁸ Induction heating has been shown to

drive catalytic depolymerization, because the catalyst surfaces heat from within, facilitating both pore diffusion and reaction.

Decarbonization Contributions from Coastal Marshes

The coastal marshes of Louisiana cover approximately 10,700 square miles and comprise approximately 12 percent of the nation's coastal wetlands. Coastal marshes are an important carbon sink, removing carbon dioxide from the atmosphere and converting it to plant biomass, comparable to the Amazon rain forest. In three recent chemical engineering Ph.D. dissertations, by S. Hacker, H. Trivedi, and S. Vora, now available at www.mpri.lsu.edu, a simulation of estuarine ecosystems to identify the critical variables to predict estuarine behavior from internal and external changes has been created.

Tidal marshes are normally categorized into two distinct zones, the lower or intertidal marsh and the upper or high marsh. In saline tidal marshes, the lower marsh is normally covered and exposed daily by the tide. It is predominantly covered by the tall form of Smooth Cordgrass (*Spartina alterniflora*). The saline marsh is covered by water only sporadically and is characterized by Short Smooth Cordgrass, Spike Grass, and Salt meadow Rush (*Juncus gerardii*). Saline marshes support a highly specialized set of life adapted for saline conditions. Tidal marshes also provide vital food and habitat for clams, crabs, shrimp, and juvenile fish, as well as offering shelter and nesting sites for several species of migratory waterfowl.



Spartina alterniflora marsh surrounds the city of Golden Meadow and was the inspiration for the city's name.

Since 1990, the Coastal Wetlands Planning, Protection, and Restoration Act Program has served as the primary means for responding to coastal wetland loss in Louisiana. Each year, large-scale restoration projects are approved for funding by the CWPPRA Task Force. The Task Force is composed of the State of Louisiana and five participating federal agencies: NOAA, U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, USDA Natural Resources Conservation Service. NOAA has been the federal sponsor for more than 40 wetland restoration projects through the CWPPRA Program. More than 12,500 acres of vulnerable coastline have been restored and helped build the resilience of coastal communities.

An accurate simulation of estuarine ecosystems has been developed to identify the critical variables to predict estuarine behavior from internal and external changes. The simulation is based on conservation equations for mass, momentum and energy, rate equations and equilibrium equations which were validated using field and laboratory data. The development of mathematical expressions describing the biogeochemical cycling of nitrogen and biomass dynamics as they occur in the Barataria Bay region of southeast Louisiana was a prerequisite to the formation of a system model.

Barataria Bay is bounded on the east by the levees of the Mississippi River, on the west by Bayou Lafourche, on the north by the Intercoastal Waterway with flow into the bay from the Intracoastal Waterway system, and the south side by barrier islands with tidal fluctuations through the passes between the barrier islands. These expressions were necessary to formulate an overall, comprehensive, large-scale model of the nutrient transport phenomena that take place in estuarine ecosystems, and which significantly account for the high productivity of these areas. The rate expressions and their development in addition to the boundary and initial conditions required to solve the hydrodynamic and materials transport equations that constitute the simulation model are reported. Rate expressions were developed for important nutrients, including a live and a dead standing crop of *Spartina alterniflora*, settled coarse detritus, fine suspended detritus, dissolved organic nitrogen, two forms of dissolved inorganic nitrogen, animal biomass, and phytoplankton biomass. Procedures

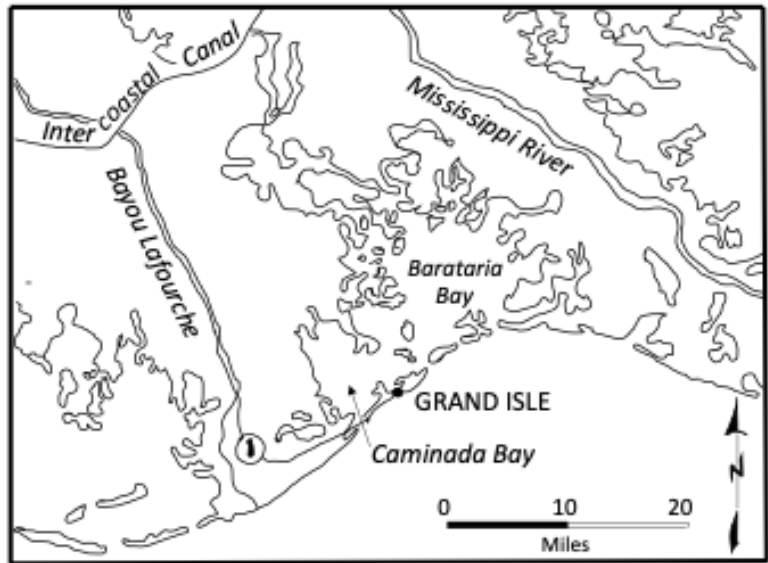


Figure 1 Map of the Barataria Bay Region, Louisiana

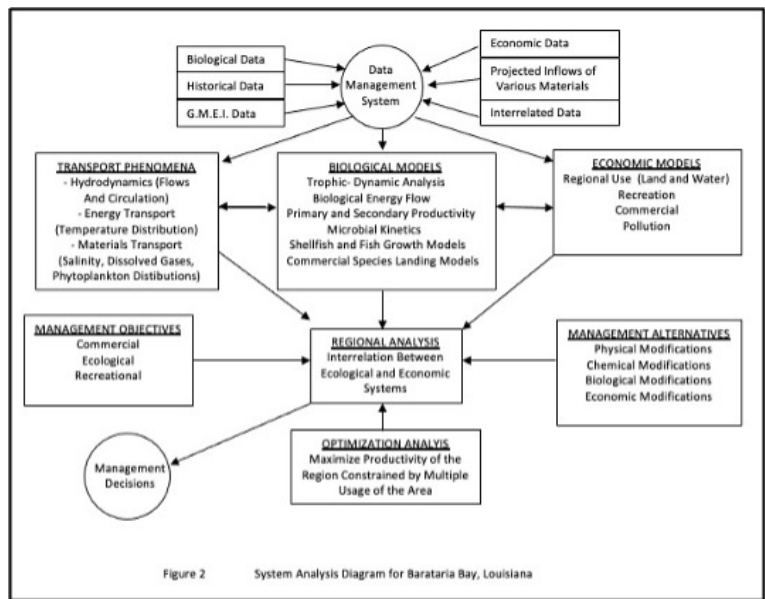


Figure 2 System Analysis Diagram for Barataria Bay, Louisiana

are given to evaluate rate coefficients that appear in the rate equations used to describe this nutrient cycling. Applications of the simulation results were used to predict the performance of the estuary to maximize the utility of this important natural resource as well as to indicate situations in which the survival of the system is jeopardized. The simulation can provide the mechanism to test management decisions and determine the response before taking the action on the actual system. The vast importance of estuarine systems like Barataria Bay for minerals and seafood production, recreational use, etc., greatly intensifies the importance of having an accurate analysis that can provide a better understanding for wiser and more efficient use of this precious resource.

References:

Ripple, T. M., et al., Species loss and nitrogen pollution alter litter decomposition dynamics in coastal salt marshes, *Oecologia* (2022) 200:479–490.

Trivedi, Hasitkumar K., Transport Phenomena in A Bay-Marsh System, Ph.D. Dissertation, Louisiana State University, August 1976.

MPRI Website, Publications, and Programs

A new website www.optimizeplants.com has been developed for MPRD to update and extensively revise the current one www.mpri.lsu.edu. It includes new research results including journal articles, conference proceeding, technical reports, theses, dissertations, and computer programs. The new web site also includes a new professional development, self-study course for professional engineers' PDH requirements and updates the others. To complete the revisions, the assistance of a computer analyst is needed who is knowledgeable of LSU IT's requirements for use of Omni CMS.

Personnel

Ralph W. Pike, Ph. D., director, Horton Professor of Chemical Engineering

F. Carl Knopf, Ph. D., associate director, Anding Professor of Chemical Engineering

Kerry Dooley, Ph.D., research collaborator, BASF Professor of Chemical Engineering

Michael Cohen, chemical engineering graduate student



Radiation Safety

Wei-Hsung Wang, Director | lsu.edu/radiation-safety

The LSU Radiation Safety Office (RSO), under the direction of the interdepartmental University Radiation Safety Committee (RSC) and with the administrative support of the Center for Energy Studies, is in charge of developing and implementing radiological control policies and procedures, as well as ensuring sound radiation safe practices, to not only comply with federal/state regulations and license/registration conditions but also assure adequate protection of people, the environment, and the integrity of the University. The RSO is a unique, imperative, and independent academic unit that directly supports and actively engages in research, teaching, and clinical activities involving the use of sources of ionizing and non-ionizing radiation at LSU.

The LSU System's broad-scope Radioactive Material License, issued by the Louisiana Department of Environmental Quality (LDEQ), allows the University maximum flexibility to accomplish legitimate and realistic education objectives through the effective and efficient operation of a regulatory-mandated radiation protection program carried out by the RSO. Administrative authorization for the radiation protection program from the University is stipulated in the LSU System's Permanent Memorandum No. 30 (PM-30): Radiation Protection Program. Enforcement actions for radiation safety violations are authorized under the LSU Policy Statement 99 (PS-99): Radiation Safety Violations. In addition, the LSU System's Safety Procedures for Non-Ionizing Radiation governs the non-ionizing radiation safety program.

In fiscal year 2021-2022, the RSO reviewed and approved 64 grant proposals involving the use of radioactive materials, radiation producing equipment, or Class 3B and Class 4 laser systems. Funds requested by these proposals were \$47,446,801. Actual funds granted to LSU were \$26,001,624. At the time of writing, twenty-seven out of the 64 grant proposals were still under review by the funding agencies. Currently, there are 869 approved radiation workers (including 81 radiation principal investigators) in 165 radiation laboratories with 5,864 annual radiation monitoring devices issued under the LSU's radiation protection program. The program covers the Agricultural Center and its research stations, the Pennington Biomedical Research Center (PBRC), and associated facilities under LSU, such as the Center for Advanced Microstructures and Devices (CAMD),

the National Center for Biomedical Research and Training (NCBRT), and the School of Veterinary Medicine (SVM). The RSO provides training and monitoring for radiation workers and performs routine surveys, inspections, survey meter calibrations (78 meters of different types), leak tests, and radioactive waste management to fully meet regulatory requirements and license/registration specifications. In addition, the RSO evaluates and inspects inventoried Class 3B and Class 4 laser systems for laser intrabeam hazards and provides laser safety training. There are 83 active Class 3B and Class 4 laser systems, 71 approved laser users (including 22 laser principal investigators), and 38 laser laboratories.

Inspections

Louisiana Department of Environmental Quality Inspections Conducted

There were four compliance and enforcement inspections conducted by the LDEQ's Emergency and Radiological Services Division, Radiation Section, in 2022.

In April, two inspectors visited the RSO and carried out inspections of the broad-scope Radioactive Material License, the physical protection of category 1 and category 2 quantities of radioactive material (PPQRM), and the radiation-producing equipment at LSU. The inspectors reviewed the records of membership and meeting minutes of the RSC, organization chart of the RSO, authority of LSU's radiation protection program and enforcement, annual radiation protection and ALARA programs review, the National Source Tracking System, and review/approval/renewal/deactivation of authorization to use sources of radiation. They also inspected radiation safety training and examinations, inventory and leak tests of sealed radioactive sources, frequency of the leak tests, and the ordering, receiving, and delivering of sources of radiation. In addition, the inspectors reviewed personnel and environmental radiation monitoring, radiation laboratory contamination surveys and audits, radiation survey meters, and preparation, disposal, and shipment of radioactive waste, as well as designated Reviewing Officials, individuals granted unescorted access, and policy, program, and procedure requirements under PPQRM regulations (e.g., maintenance and service as well as alarm drill and testing of surveillance equipment, review of security and access authorization programs, refresher training, protection of physical and sensitive information, pre-arranged plan with the local law enforcement agency [LLEA], and an annual meeting with the LLEA).

The inspectors also inquired about radiation laboratory close-out procedures, deactivation of approved radiation principal investigators, corrections, enforcement actions, and the appeal process for internal violations.



Amin M. Hamideh and John Paul Lockett conduct an inspection of a newly installed computed tomography scanner at the LSU School of Veterinary Medicine.

They looked into RSO's emergency procedures for radiation spills, the current status of approved radiation principal investigators, radiation workers, personal radiation monitoring devices, and radiation laboratories, in addition to administrative limits for occupational radiation exposure, investigation of elevated personal exposure, functions and applications of the Health Physics Assistant database management software. Finally, they inspected quality assurance/quality control (QA/QC) and operation of radioanalytical equipment, release of liquid radioactive waste, and point of contact at the LLEA.

The inspectors also looked over LSU's Radioactive Material License, the Radiation Safety Manual, and the radioactive waste management process. They walked through the radioactive package receiving area, the radioactive material storage area, three radioanalytical laboratories, the radioactive waste storage facilities, and the PPQRM security zones of the RSO. They also conducted an alarm drill to observe the response by the LLEA and interviewed the responding LSU police officers regarding the response plans and training. Furthermore, they visited 16 additional radiation laboratories under LSU's radiation protection program. During the laboratory visits, they checked inventoried source location, radiation levels, function and calibration of in-laboratory survey meters, posting and barrier requirements, secured storage of radioactive materials, disposal of radioactive and mixed waste, the Radiation Safety Manual, and registration certificates. They also reviewed the source inventory and disbursement logs, the annual in-laboratory training records, the in-laboratory radiation surveys, and the functions of fume hoods. In addition, the leading inspector observed and questioned the approved radiation workers (i.e., faculty members, laboratory managers, clinical technologist, and graduate students) about the research/clinical purposes and protocols involving uses of radiation sources, designated radiation areas, wearing of personal radiation monitoring devices, patient workload and release limits, criteria for bioassay, operation and QA/QC of radioanalytical and radiotherapeutic equipment, physical operational parameters and safety features of radiation producing equipment, procedures of ordering, receiving, and storage of radioactive materials, and practice for radioactive waste labeling/storage/disposal.



Amin M. Hamideh, Ji Young Wiley, and Melissa H. Esnault carry out an inspection on radiation interlock systems at the J. Bennet Johnston, Sr., Center for Advanced Microstructures & Devices (CAMD).

After the walk-through, an exit interview was held and no areas of concern were listed on the LDEQ's Field Interview Form.

In December, an inspector visited the PBRC to conduct an inspection of the radiation-producing equipment there. The inspector checked the posting requirements, inquired about documentation for the QA/QC protocols, personnel monitoring program, and internal inspection practice, interviewed the authorized radiation workers regarding applications of the radiation-producing equipment, and observed operation of the radiation-producing equipment. Specifically, the inspector visited the radiation laboratories under LSU's radiation protection program that included six X-ray units. For the radiographic X-ray unit, the inspector checked light field vs. radiation field, timer (i.e., exposure duration) accuracy, exposure reproducibility, accuracy of tube potential (kV), linearity of tube current (mA), technique chart, and dosimetry on authorized personnel. The inspector also inquired about credentials of the operators, use of various phantoms for QA/QC, and typical workload. For the dual energy X-ray absorptiometry units, the inspector asked about the energy output, use of various phantoms for QA/QC, scan times, and typical workload. For the analytical computed tomography (CT) units, the inspector examined the shielding containment, checked the "search and secure" practice and the interlock system, and asked about the standard operating procedures of the CT units.

After the walk-through, an exit interview was held and no areas of concern were listed on the LDEQ's Field Interview Form.

Revision of *Radiation Safety Manual*

In accordance with the renewal of the LSU System's radioactive material license, the Radiation Safety Manual was also revised. The updated Radiation Safety Manual now meets the federal requirements for digital resource and content accessibility and is available online.

Professional Contributions and Recognitions

American Board of Health Physics Honors Wang with McAdams Award

Dr. Wei-Hsung Wang, RSO director and Center for Energy Studies professor, was the recipient of the 2022 Williams A. McAdams Outstanding Service Award presented by the American Board of Health Physics (ABHP) (his citation can be found at <https://www.aahp-abhp.org/abhp/awards/mcadams/2022>). The award has been presented annually since 1989 to honor a certified health physicist who has made significant contributions toward professionalism in health physics and to the certification process.

Established in 1959, the ABHP grants professional certification in the field of health physics. The certification process is accredited by the Council of Engineering and Scientific Specialty Boards. Health physics is the area of environmental health engineering and public health that engages in the safe use of ionizing and non-ionizing radiation in order to protect individuals, the general public, and the ecosphere from potential harmful effects of the radiation. The health physicist is responsible for safety and security aspects in the design of processes, equipment, and facilities utilizing radiation sources as well as for adequate disposal of radioactive waste so that radiation exposure to personnel will be minimized and will at all times be within regulatory limits.

Wang is a member of the ABHP (Vice Chair 2020; Chair 2021) and Fellow of the Health Physics Society. He has served on various advisory capacities for both federal and state government agencies including the U.S. Environmental Protection Agency, the U.S. National Oceanic and Atmospheric Administration, the U.S. Nuclear Regulatory Commission, the Louisiana Department of Environmental Quality, and the Louisiana Department of Health.



Wei-Hsung Wang gives an acceptance speech at the American Academy of Health Physics/American Board of Health Physics award luncheon.

Wang appointed to the U.S. Environmental Protection Agency Radionuclide Cancer Risk Coefficients Review Panel

Dr. Wei-Hsung Wang, RSO director and Center for Energy Studies professor, was invited to serve as a member of the Radionuclide Cancer Risk Coefficients Review Panel of the U.S. Environmental Protection Agency (EPA) Science Advisory Board (SAB). This Panel will provide independent advice on the EPA's draft Update to Cancer Risk Coefficients for Environmental Exposure to Radionuclides (Federal Guidance Report No. 16). FGR 16 provides radionuclide-specific lifetime radiogenic cancer risk coefficients for incidence and mortality associated with internal exposure to radionuclides through inhalation of contaminated air and ingestion of contaminated water or food, and external exposure to radionuclides distributed in air, water, and soil.



Wang is one of 17 panelists, who represent academia (LSU, North Carolina State University, Northwestern University, University of California at San Francisco, University of Southern California, and Washington State University), government agencies (Lawrence Berkeley National Laboratory, National Institutes of Health, Pacific Northwest National Laboratory, Sandia National Laboratory, and Washington Department of Health), research institute (Radiation Effects Research Foundation), and private industry (Renaissance Code Development).



RSO reunion at the 67th Annual Meeting of the Health Physics Society in Spokane, Washington: (left to right) Daniel J. DiMarco, U.S. Nuclear Regulatory Commission health physicist (former RSO technical assistant); Dr. Wei-Hsung Wang, LSU RSO director and Center for Energy Studies professor; Li-Yen Chen, Mirion Technologies dose analysis lead (former RSO visiting scholar); and Andrew D. Hastings, Sandia National Laboratory health physicist/radiological engineer (former LSU CAMD acting radiation safety officer)

Scholarly Activities

Grant Awarded

By Wei-Hsung Wang

- ▶ LSU nuclear multidisciplinary scholarship program. Co-Investigator, U.S. Nuclear Regulatory Commission; award amount: \$199,998 (2022-2024).

Grants Submitted

By Wei-Hsung Wang

- ▶ Microphysical behavior and transport of hygroscopic radiological debris. Principal Investigator, U.S. Nuclear Regulatory Commission; requested amount: \$460,178 (2022-2025).
- ▶ LSU nuclear multidisciplinary fellowship program. Co-Investigator, U.S. Nuclear Regulatory Commission; requested amount: \$400,000 (2023-2027).
- ▶ Novel module for separation of radionuclides from aqueous solutions. Co-Investigator, Louisiana Board of Regents; requested amount: \$40,000 (2023-2024).
- ▶ Electrosorption module to treat liquid radioactive wastes. Co-Investigator, LSU Board of Supervisors; requested amount \$30,000 (2023-2024).

Conference Presentations

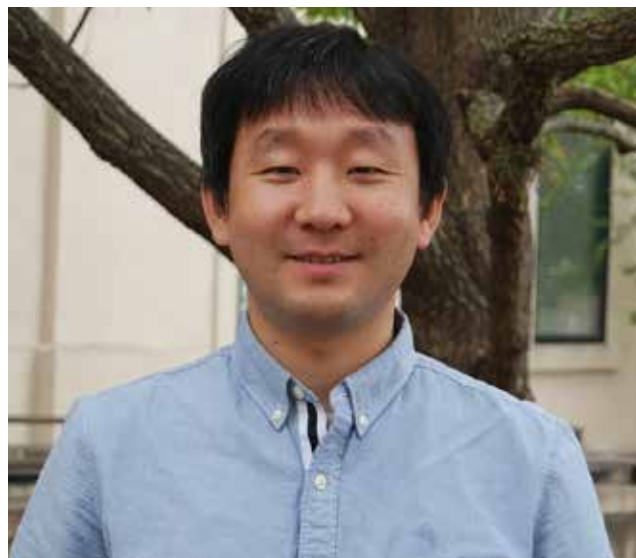
- ▶ Zimmerman C, Chen L-Y, Wang W-H, Matthews II KL. Comparative analysis of global trend in the occupational dose of medical radiation workers. The 2022 Health Physics Society/International Radiation Protection Association North American Regional Congress, February 20-23, St. Louis, MO, 2022.
- ▶ Hamideh AM, Wang W-H. Developing calibration conversion factors for iodine-131 in a silver zeolite cartridge using barium-133 as a surrogate. The 2022 Health Physics Society/International Radiation Protection Association North American Regional Congress, February 20-23, St. Louis, MO, 2022.
- ▶ Chen L-Y, F Hsu, Kao W, Liu R, Liu Q, Wang W-H. Investigation of the background radiation level around Maanshan nuclear power plant in Taiwan with aerial radiation detection technology. The 2022 Health Physics Society/International Radiation Protection Association North American Regional Congress, February 20-23, St. Louis, MO, 2022.
- ▶ Wang W-H. The American Board of Health Physics certification process. The 2022 Health Physics Society/International Radiation Protection Association North American Regional Congress, February 20-23, St. Louis, MO, 2022.

Journal Manuscripts Reviewed

By Wei-Hsung Wang

- ▶ Paper HPJ-D-22-00157 "Relationship between cancer and radiation: A new paradigm". Reviewed for *Health Physics*, 2022 (Brant Ulsh, Editor-in-Chief).
- ▶ Paper HPJ-D-22-00020 "Pilot study of thoron concentration in an underground thorium mine ". Reviewed for *Health Physics*, 2022 (J. Matthew Barnett, Associate Editor).

Personnel News



Dr. Yong-Ha Kim, Assistant Professor in the Department of Environmental Sciences, was recommended unanimously by the RSC to become a member of the RSC. Dr. Kim is an authorized radiation principal investigator and possesses proficient working knowledge and experience in the areas of radiochemistry, transport of radioactive aerosols, and radiation protection. Per LSU PM-30, Dr. Kim's appointment was officially confirmed by LSU President William F. Tate IV, with the approval of Dr. Dennis Paul, Chair of the LSU System RSC.

Personnel

Administration

Wei-Hsung Wang, Ph.D., CHP, CSP, CLSO, FHPS, director & professor

Amin M. Hamideh, M.S., CLSO, manager-operations & laser safety officer

Nicholas T. Desselles, M.S., radiation safety coordinator & laser safety officer

Ji Young Wiley, M.S., CAMD radiation safety officer

Melissa H. Esnault, business officer

L. Abbigail Granger, D.V.M., DACVR, LSU SVM liaison

Christy L. White, D.V.M., PBRC liaison

Technical Assistants

Lily Antor

Adam Curet

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Designed by Stephen W. Radcliffe.

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