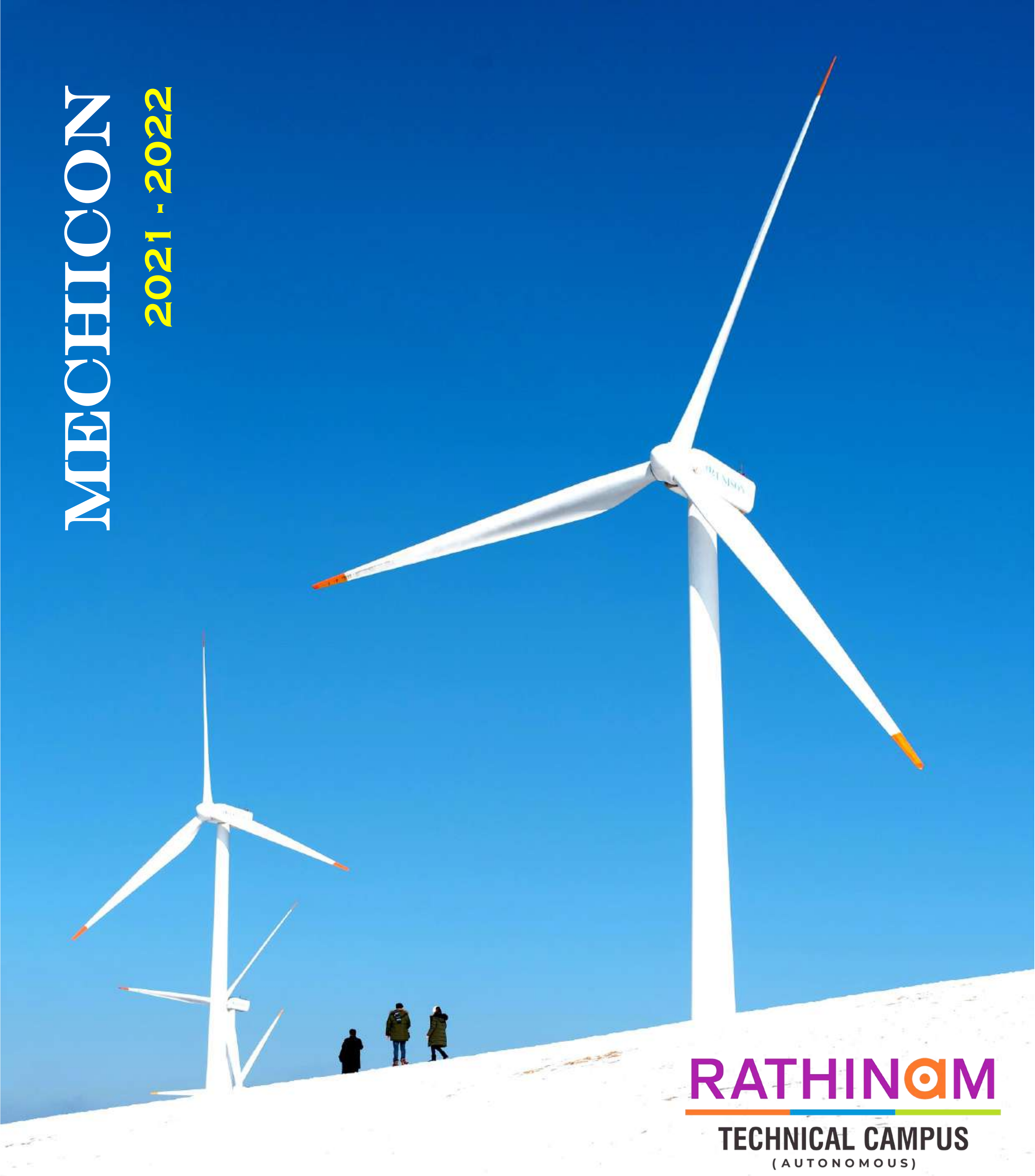
MECHICON

2021 - 2022



RATHINAM
TECHNICAL CAMPUS
(AUTONOMOUS)

Mechanical

Engineering

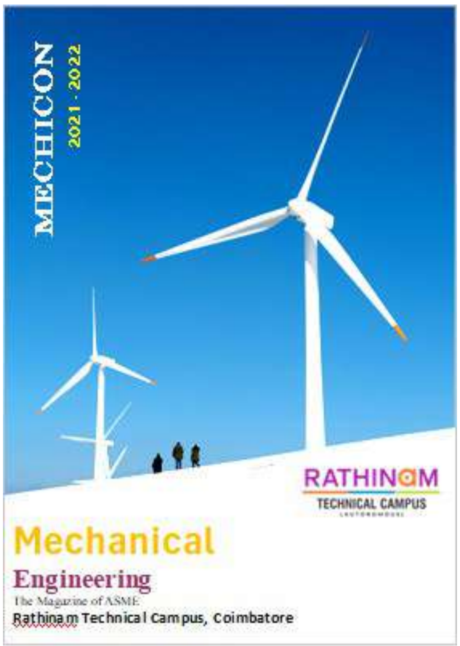
The Magazine of ASME

Rathinam Technical Campus, Coimbatore

CONTENTS

VISION OF THE INSTITUTE

To be a leading and path-breaking Institution in multi-disciplinary education, research, and industry-related development for meeting the challenges of a New India.



Cover Page

MISSION OF THE INSTITUTE

M1. Provide quality Engineering Education, Foster Research and Development, inculcate innovation in Engineering and Technology through state-of-the-art infrastructure.

M2. Nurture young men and women capable of assuming leadership roles in society for the betterment of the country.

M3. Collaborate with industry, government organizations, and society for curriculum alignment and focused, relevant outreach activities.

Dr. Madan A. Sendhil

Chairman, Rathinam Group of Institutions

Welcome to Rathinam Technical Campus, where we empower students to become the leaders of tomorrow. We believe that education is not just about learning facts and figures, but about shaping individuals who can make a positive impact on the world. Our approach to education is unique, as we focus not only on academic excellence but also on fostering creativity, innovation, and a sense of social responsibility. Our modernized facilities, experienced faculty, and innovative teaching methods enable students to gain the knowledge and skills they need to excel in their chosen fields. We encourage students to think beyond the classroom and participate in various co-curricular and extra-curricular activities that help them develop their personalities and discover their true potential.

At RTC, we are committed to providing our students with a holistic education that prepares them for the challenges and opportunities of the 21st century. We aim to create a community of lifelong learners who are dedicated to making a positive difference in the world. Join us and unlock your potential today!

Dr. Madan A. Sendhil

Dr. B. Nagaraj M.E., Ph.D., MIEEE, MSEEE, MIIOT, MIPSES, MIEEC.,

Principal, Rathinam Technical Campus

As we embark on a journey of higher education, we must remember that it is not just about textbooks and assignments, but also about excelling in every aspect of life. The world around us is in a constant state of transformation, and it is imperative that we equip ourselves with the necessary skills and knowledge to adapt and thrive in this rapidly changing landscape.

At our institution, we are committed to providing our students with a holistic education that not only hones their technical abilities but also instills in them the values and principles necessary to succeed as compassionate and ethical professionals. Our unique approach, rooted in the principles of Design Thinking, empowers our students to think critically, creatively, and empathetically, ensuring that they are not just proficient in their chosen fields but also equipped to make a positive impact on society.

We believe that education is not just a means to an end but a lifelong pursuit, and we encourage our students to keep their passion for learning alive by embracing the concept of "JUST LOVE YOURSELF". By prioritizing personal growth, celebrating life's moments, and nurturing our conscience, we can create a better future for ourselves and those around us. Let us come together and embrace this journey of self-discovery and transformation.

Dr. B. Nagaraj

Dr. M. Rajasankar M.E., Ph.D.,

HEAD OF THE DEPARTMENT

The department of Mechanical Engineering aims to provide a strong foundation in the fundamentals of Mechanical Engineering. The basic knowledge of analysis as well as the knowledge of the principles on which Mechanical Engineering is based taught through the theory and laboratory classes by a strong team of Well Qualified and Experienced Teaching Staff and the Technical Support Staff. The department also strives to instill the engineering temper and the spirit of enquiry in students. It encourages the students to understand and therefore apply the laws through the laboratory classes. The Department has well equipped laboratories such as Basic Workshop Lab, Machines Shop Lab, Computer Aided Machine Drawing Lab, Mechanical Measurements Lab, Material Testing Lab, Heat Transfer Lab, Energy Conversion Lab, Fluid Mechanics & Machines Lab, Heat & Mass Transfer Lab, Design Lab, Computer Aided Analysis Lab to perform the practical's to understand the concepts.

VISION OF THE DEPARTMENT

To emerge as a leading influence in Mechanical Engineering education, research, and advancements driven by industry, making a substantial contribution to the transformative growth of the Nation.

MISSION OF THE DEPARTMENT

M1 : Deliver top-tier Mechanical Engineering education, promote a culture of research and innovation, and leverage state-of-the-art infrastructure to stay at the forefront of Engineering and Technology.

M2 : Nurture future leaders in Mechanical Engineering, empowering them to take on pivotal roles in society and contribute significantly to the nation's advancement.

M3 : Foster dynamic collaborations with industry, government bodies, and society, ensuring curriculum alignment with evolving industry needs and engaging in targeted outreach activities to bridge the gap between academia and industry for mutual growth..

PEO NO.	PROGRAM EDUCATIONAL OBJECTIVES (PEOs)
PEO 01	Graduates will have professional & technical career in mechanical and inter disciplinary domains providing innovative and sustainable solutions using modern tools.
PEO 02	Graduates will have effective communication, leadership, team building, problem solving, decision making and creative skills.
PEO 03	Graduates will practice ethical responsibilities towards their peers, employers, and society

The department provides its students with a number of opportunities to develop their overall personality by participating in the various Curricular, Co-Curricular and Cultural activities held throughout the year .The students with the directions from faculty members of the department take very active part in organizing these activities.

Dr. M. Rajasankar M.E., Ph.D.,

PROGRAM OUTCOMES (POs)

PO1 - Engineering Knowledge
PO2 - Problem analysis
PO3 - Design / Development of Solutions
PO4 - Conduct Investigations of Complex Problems
PO5 - Modern Tool Usage
PO6 - The engineer and society:
PO7 - Environment and Sustainability
PO8 - Ethics
PO9 - Individual and Team work
PO10 - Communication
PO11 - Project Management and Finance
PO12 - Life-long Learning

Program Specific Outcome (PSOs)

PSO NO.	PROGRAM SPECIFIC OUTCOMES (PSOs)
PSO 01	Application of Mechanical Engineering concepts to solve Engineering problems using modern tools and techniques.
PSO 02	Identify and recommend alternative Engineering methods and materials for sustainable development.

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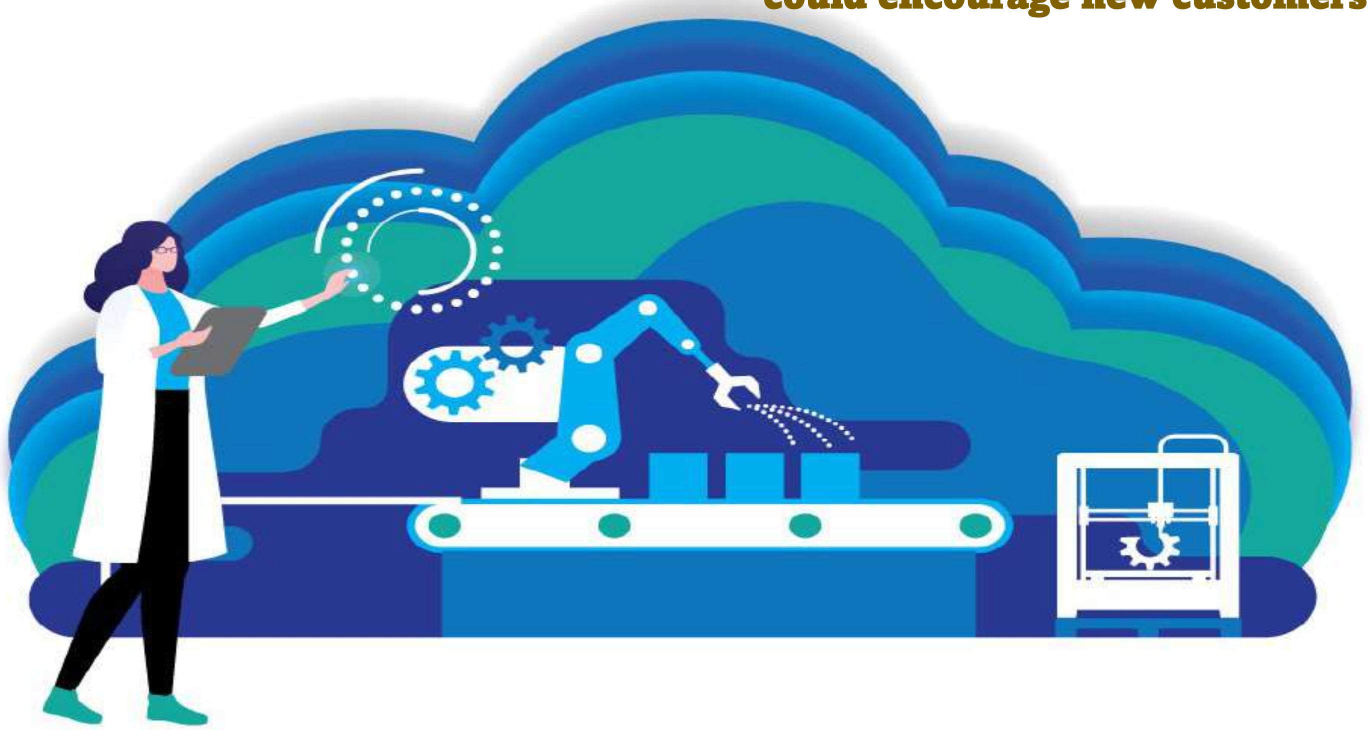
STUDENTS' ARTICLE

Exposing misunderstandings about electric cars could encourage new customers



For nearly a decade, I drove a hybrid vehicle—a 2010 Ford Fusion Hybrid. It was an excellent car with interactive features like an LCD screen displaying green leaves to indicate eco-friendly driving. It became a game to see how long I could stay in battery mode or optimize the hybrid mode. I achieved 40 miles per gallon and a 600-mile range.

Since losing that car in an accident, I've been eager to invest in a fully electric vehicle (EV). However, I often face the same questions: Where will you charge it? Can you drive long distances with an EV? Is buying an electric car really more environmentally friendly.

As EVs gain popularity, let's address some common myths highlighted by the U.S. Environmental Protection Agency (EPA) to help future buyers make informed decisions.

Myth #1: Power Plant Emissions Will Rise

A frequent concern is that power plant emissions will increase due to the higher demand on the grid from electric vehicles. In reality, emissions from power plants depend on how local power is generated. EVs produce no tailpipe emissions, resulting in a lower overall carbon footprint compared to gas-powered vehicles. Research by the EPA and the U.S. Department of Energy (DOE) indicates that EVs typically generate fewer greenhouse gases (GHGs). According to the U.S. Department of Transportation, vehicles were the largest source of GHGs, contributing 29 percent in 2019, with around 267 million vehicles on the road. Converting these vehicles to electric would significantly reduce emissions.

STUDENTS' ARTICLE

Although this concern has some validity, it does not tell the whole story. The National Renewable Energy Laboratory has been monitoring trends in alternative fueling stations since the 1990s. Their quarterly report, "Electric Vehicle Charging Infrastructure Trends from the Alternative Fueling Station Locator," tracks the availability of charging stations nationwide. At the end of the first quarter in 2020, there were 79,465 public electric vehicle supply equipment (EVSE) stations or docks available. By the end of 2020, this number had increased to 96,190, marking an almost 21 percent rise within a single year. President Biden's new infrastructure initiative, The American Jobs Plan, allocates $174 billion for EV development, including incentives for automakers, subsidies for drivers, and the expansion of public EV charging stations.

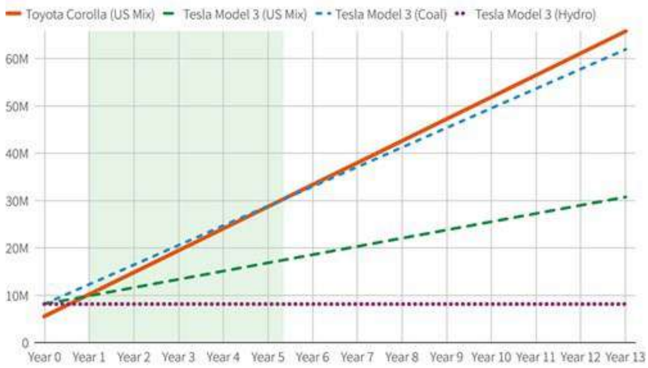
Myth #2: Electric Cars Cannot Drive Very Far

According to the EPA, the average household drives 50 miles per day, with most trips being under 100 miles. Most electric vehicles (EVs) can handle daily driving needs, although this depends on the specific vehicle, its operating conditions, and the environment. Currently, many top EVs offer ranges of 250 miles or more. Edmunds reports that the Tesla Model 3 Long Range tops the list with a range of 353 miles per charge. Other models, such as the new Ford Mustang Mach-E and the Hyundai Kona Electric, offer ranges of 344 and 315 miles, respectively. This marks a significant improvement from just a year ago when Car and Driver magazine's 2020 EV range test estimated an average range of 200 miles among the leading vehicles.

Of course, this depends on how the car is driven. Extreme weather conditions can affect battery performance, with research indicating that an EV's range can decrease by 40 percent in cold temperatures. Additionally, the use of climate control features can impact battery efficiency. For instance, Car and Driver reports that using the heater to warm the cabin in a Tesla Model 3 Long Range can reduce battery performance by up to 35 percent.

Myth #3: Battery Manufacturing is Worse for the Environment

A former colleague often argued that the environmental impact of manufacturing an EV battery is worse than the emissions produced by a gas car over its lifetime. According to the EPA, some studies indicate that building an EV, especially the battery, generates more carbon emissions than manufacturing a gasoline vehicle. However, throughout their lifetimes, EVs emit fewer greenhouse gases (GHGs) than gas cars.



Note: Total lifetime CO2 emissions in millions of grams
Data source: Argonne National Laboratory GREET model

Researchers at Argonne National Laboratory developed the Greenhouse Gases, Regulated Emissions, and Energy use in Technologies (GREET) model to simulate the energy use, emissions, and fuel combinations of different vehicles. This model accounts for the full lifecycle of fuel creation, including drilling, refinement, and sales, as well as vehicle manufacturing, from material sourcing and battery creation to chassis assembly and recycling impacts. The consensus is that while EV production may have a higher initial environmental impact, the overall GHG emissions are lower than those of gas cars due to the absence of tailpipe emissions.

As we increasingly rely on renewable energy, the carbon footprint of EVs is expected to decrease further. In a scenario where energy is produced exclusively by hydroelectric power, the Tesla Model 3 reached environmental parity at just 8,400 miles.

Electric cars represent the future, and their widespread adoption will determine how quickly this transition happens.

RAMKUMAR V
721820114015 , II MECH

STUDENTS' ARTICLE

Engineers are working on enhancing ventilation systems to make gathering places, such as offices and restaurants, safer.

Engineers consider themselves problem solvers, and the COVID-19 pandemic has presented an unparalleled challenge. While vaccines are being produced and distributed, engineers are focusing on indoor spaces, which have been linked to the virus's spread. Even after achieving population immunity, improving indoor air quality will remain a significant concern.

The primary reason the U.S. economy suffered in 2020 was that the virus made it unsafe to gather in offices, restaurants, and other indoor areas. Viruses often spread through aerosols and airborne droplets, which can be inhaled by healthy individuals. Even before COVID-19, viruses like the common cold and flu could easily spread in workplaces as microbes traveled from cubicle to cubicle.

As people return to work, the first line of defense will include HVAC engineers working to make buildings safer. This is an issue that could have been addressed years ago, according to William Bahnfleth, a mechanical engineering professor at Pennsylvania State University and former president of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). "Improving indoor air quality was something I advocated for 15 to 20 years ago, based on research showing that our minimum standards were inadequate," Bahnfleth said. "We could achieve better performance, reduce sick leave and symptoms of sick-building syndrome, and improve school performance. There are many reasons to go beyond just asking, 'Does the air smell OK to you?'"

The technology to ensure safety already exists. What has been lacking is the acknowledgment that providing these protections is the responsibility of anyone who constructs and operates a building.

NIBI NARAYANAN
721819114007 , **III MECH**

Indoor air quality has been recognized as a health issue since the 1850s, but HVAC engineers have typically prioritized achieving comfortable temperatures and humidity levels in an energy-efficient manner. This has often involved creating "tighter" buildings through better windows, doors, sealing practices, and construction techniques.

However, sealing buildings brought about other concerns: Were occupants getting enough oxygen? Was there a buildup of toxic chemicals? Were tiny particles circulating through the air? Even before COVID-19, filters were recommended in HVAC systems to address some of these issues. However, increasing filter density to capture smaller particles also increases pressure drop, potentially reducing airflow.

As a result, high-efficiency particulate air (HEPA) filters, which must be at least 99.97 percent efficient at capturing particles 0.3 micrometers in size, are not generally recommended for large systems. They are more suitable for portable room-sized units, where their lower airflow can still be somewhat effective. Still, as William Bahnfleth, a mechanical engineering professor at Pennsylvania State University and leader of ASHRAE's COVID-19 Task Force, said, "adding filters is a no-regrets policy" because they improve building health overall.

Bahnfleth also identified two other measures to protect indoor air from viruses: dilution and deactivation.

Dilution is supported by the low incidence of coronavirus transmission outdoors and research in hospitals showing the importance of proper ventilation. Reducing the virus concentration in the air increases the required exposure time for infection.

To decrease the amount of airborne virus indoors, the Federation of European Heating, Ventilation, and Air Conditioning Associations recommends using no recirculated air, continuously bringing in fresh outdoor air without mixing it with recirculated air. They also suggest flushing buildings for two hours before occupancy. In the U.S., however, variable air volume (VAV) systems, standard in office buildings, use significant amounts of recirculated air passed through filters and mixed with outside air. According to Bahnfleth, these systems often provide five to six times more air movement through a space than a fresh-air-only system. A typical VAV system might offer six air changes per hour, with outdoor air accounting for one or two changes, potentially lowering airborne particle concentration more effectively than a 100 percent outside air system, which is costly and underutilizes filters.

Air quality researcher Kathleen Owen noted recent innovations in filtration technology. Many new filters incorporate electrostatic capture, such as synthetic non-woven filters. Filters combining mechanical and electret efficiency (built-in dipole polarization) generally outperform those relying solely on mechanical efficiency. The electrostatic effects in electret-charged media enhance submicron particle capture efficiency. Mechano-electret filters also offer lower airflow resistance, reducing energy consumption and costs. However, the effectiveness of electret filters can vary based on different treatment patterns or charge distributions.

While ventilation and filtration significantly reduce infection risk, increased airflow can spread risk throughout a building. Edward Nardell, a professor at Harvard's T.H. Chan School of Public Health, pointed out that although particles dilute in a room and die off to some extent before reaching exhaust ducts, those in close proximity to an infectious source are still at higher risk, especially as the source strength increases. Max Sherman, a retired ventilation researcher at Lawrence Berkeley Laboratory, explained that adding airflow averages out particle concentration, benefiting those nearest the source but potentially less effective for those farther away unless the overall level is sufficiently reduced.

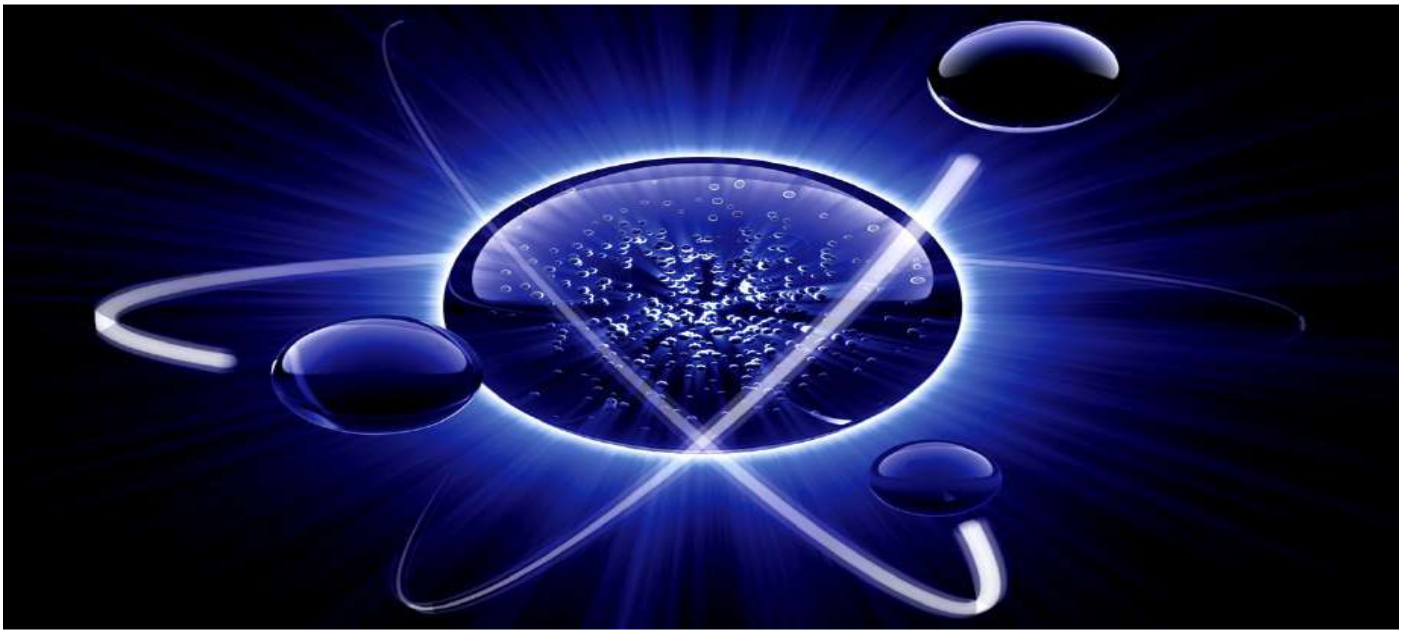
To protect those near an unknown contagious source, universal masking is effective, but engineers seek solutions beyond occupant compliance. One promising approach is ultraviolet germicidal irradiation (UVGI), which both Nardell and Bahnfleth have studied for years. UV light has been used for disinfecting air and water since the early 1900s and recently in robots to sterilize hospital

Even before the pandemic, improving indoor air quality was a growing concern. In hot, developing countries, buildings that traditionally relied on natural ventilation are rapidly installing inexpensive air conditioning systems without proper ventilation, increasing disease transmission risks. These systems need to be updated to include ventilation and possibly UV systems with the AC units.

Nardell connected air conditioning, climate change, and disease transmission in an editorial in Indoor Air last year, as COVID-19 spread globally. He wrote, "The escalating use of air conditioning globally is directly resulting in conditions favoring increased person-to-person transmission of airborne infections such as tuberculosis, influenza, and measles. Unlike the gradual environmental effects of increased CO2 emissions, the impact of AC on airborne infection is nearly instantaneous."

STUDENTS' ARTICLE

Entrepreneurs Are Concentrating on Small-Scale Nuclear Reactors



Nuclear power has typically been constructed in large-scale installations. However, some experts argue for the benefits of developing small, modular reactors.

In the realm of energy systems, some operate seamlessly, akin to plug-and-play household gadgets. For instance, small gas turbine plants arrive as factory-built units ready for installation, wind farms consist of identical turbines in multiples, and solar power facilities scale down to individual photovoltaic panels. This modular approach supports mass production, driving down costs.

In stark contrast, nuclear power plants have historically been far from plug-and-play. These facilities are colossal, each producing hundreds of megawatts and custom-built from scratch. The immense size necessitates redundant systems layered upon backups, adding to the already steep costs. Planning alone can span a decade, involving intricate, site-specific assessments.

Early attempts this century to construct new large light-water reactors revealed the daunting economics. Estimated at $1,500 per kilowatt, costs ballooned beyond feasibility. The Watts Bar 2 plant, completed by the Tennessee Valley Authority after a hiatus, saw expenses soar to $5 billion—approximately $4,000 per kilowatt. Starting a nuclear plant from scratch could easily reach $8 billion to $10 billion, making financing precarious and cancellations probable, as witnessed in South Carolina's Virgil C. Summer Nuclear Generating Station.

Robert Rosner, a physicist from the University of Chicago, noted the financial risks associated with gigawatt-scale nuclear plants, highlighting the uncertainty of recouping investments.

Starting a nuclear plant from scratch could easily reach $8 billion to $10 billion, making financing precarious and cancellations probable, as witnessed in South Carolina's Virgil C. Summer Nuclear Generating Station.
Robert Rosner, a physicist from the University of Chicago, noted the financial risks associated with gigawatt-scale nuclear plants, highlighting the uncertainty of recouping investments.

Some advocates in the nuclear industry propose abandoning large-scale, custom-built plants in favor of embracing small modular reactors (SMRs). These reactors, which would produce tens to a few hundred megawatts of electricity, promise lower costs, enhanced safety features, and the utilization of advanced technologies.

There are many scenarios where a one-gigawatt reactor simply doesn't make sense, regardless of cost, whereas a smaller reactor around 100 megawatts—give or take 50 percent—makes a lot of sense," remarked Robert Rosner, coauthor of the 2011 report "Small Modular Reactors—Key to Future Nuclear Power Generation in the U.S.Ironically, even concepts designed to be small, modular, and quick to build often find themselves mired in decades-long development cycles.

Small reactors are not a new concept—the Shippingport Atomic Power Station, the world's first commercial reactor, generated 60 MW of electricity. In Russia, a 70 MW power plant comprising two 35 MW reactors sits on a barge in the Arctic Ocean, supplying power to the Siberian town of Pevek. Meanwhile, China is testing two HTR-PMs, each capable of generating about 100 MW.

The NuScale Power Module is designed to be manufactured as a self-contained unit in a factory setting. It incorporates both the nuclear core and steam generator within a reactor vessel that is nested inside the containment vessel. Image credit: NuScale Power, LLC.

NuScale, based in Oregon, appears closest to overcoming the hurdles of research and development. Over the past decade, the company has been refining its Power Module—a 60 MW reactor complete with steam generator, pressurizer, and control rods, all compactly designed to fit within a 76 ft. by 15 ft. containment vessel. Unlike traditional gigawatt-scale reactors built on-site, NuScale's modules could be mass-produced in factories and transported to any location as needed.

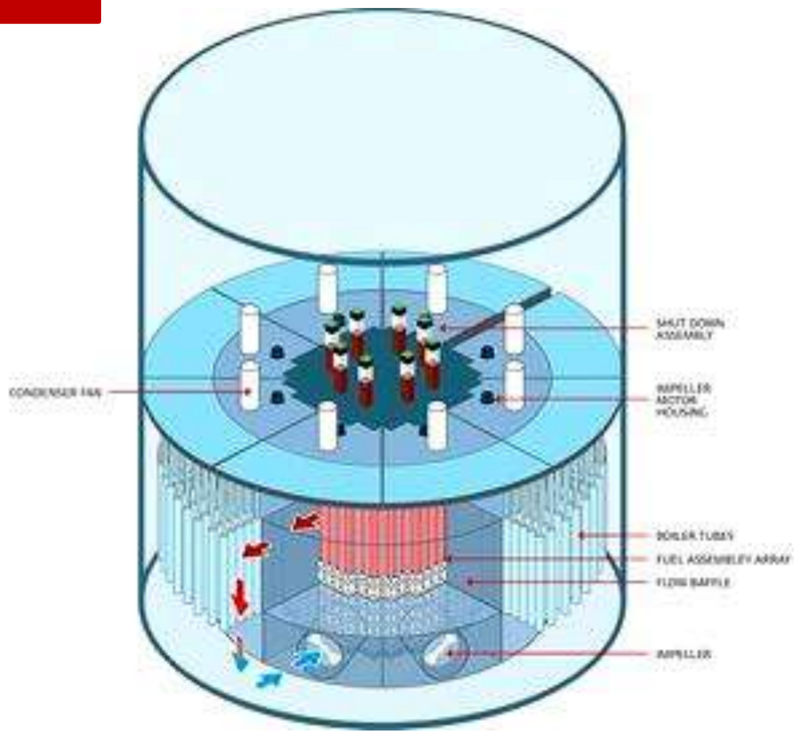
While a conventional nuclear plant serves a metropolitan area or small state, a 60 MW reactor would suffice only for a small city's electricity needs. Modularity offers a solution: utilities can purchase and install as many SMRs as required, expanding capacity incrementally rather than investing in massive power plants.

From a reactor physics standpoint, NuScale's approach is fairly standard: it utilizes low -enriched uranium and light-water cooling, similar to existing nuclear plants. José Reyes, NuScale's cofounder and chief technology officer, emphasized that sticking with a traditional design ensures cost competitiveness and facilitates near-term deployment, leveraging decades of research and operational experience with pressurized water-cooled reactors.

"In the past 50 years, pressurized water-cooled reactors have benefited from extensive research and development, as well as millions of hours of operational experience," Reyes noted. "NuScale opted for a conventional approach to streamline licensing processes and ensure cost effectiveness."

The BWRX-300 is a boiling-water reactor designed to generate 300 MWe, which surpasses the capacity of many other small modular reactors (SMRs). This reactor is planned as a direct replacement option for conventional coal-fired power plants, offering a swap-in, plug-and-play solution.

BHARATH KUMAR.A.N
721819114302 , **III MECH**



The viability of small modular reactors (SMRs) hinges on their ability to address longstanding challenges in nuclear power with innovative designs and cost-effective solutions. These reactors depart from traditional large-scale plants by integrating enhanced safety features derived from lessons such as the Fukushima disaster. For instance, NuScale's SMR operates passively, relying on natural convection to cool itself in emergencies, eliminating the need for active cooling systems and additional power sources.
Moreover, these reactors are designed to be housed underground within robust containment pools, capable of withstanding various disasters including earthquakes and airplane impacts. This design philosophy not only enhances safety but also allows for closer placement to urban centers, reducing reliance on remote locations with expansive emergency planning zones.

NuScale has made significant strides in gaining regulatory approval, with its SMR technology undergoing rigorous review by the U.S. Nuclear Regulatory Commission—the first of its kind to reach this stage. Already, the company has secured its first customer, Utah Associated Municipal Power Systems, for a planned 12-module plant at Idaho National Laboratory, scheduled for operation in the mid-2020s.
However, opinions differ on the optimal scale for SMRs. While some advocate for smaller, more manageable 60 MW units like NuScale's, others, like MIT's Jacopo Buongiorno, argue that slightly larger reactors, such as GE's BWRX-300 generating 300 MW, could offer better economic efficiency and easier integration into existing energy infrastructures, akin to replacing coal-fired plants.

Beyond conventional designs, companies like Holtec International and Moltex Energy are pioneering alternative approaches. Holtec's SMR-160 employs passive air-cooling systems ideal for arid environments, while Moltex's molten salt reactors promise to simplify designs and operational costs by using two-salt systems that eliminate the need for traditional cooling pumps and electrical systems.
Despite the promise of reduced costs—aiming for around $2,000 per kW for Moltex—achieving competitive pricing remains a critical milestone. The next decade will prove pivotal, determining whether these innovative nuclear technologies can deliver on their potential to reshape global energy landscapes.

STUDENTS' ARTICLE

Pushing Forward Battery Technology for Contemporary Innovations

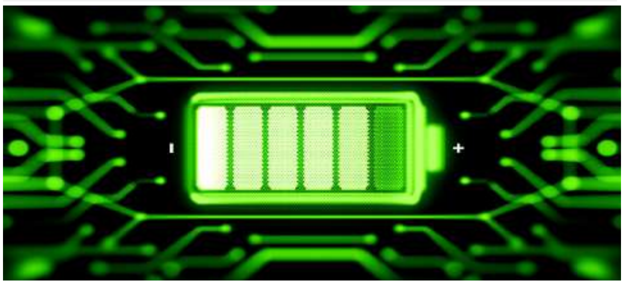
Batteries have always been a critical element in design, from handheld tools to computers, mobile phones, and applications like uninterruptible power supplies and satellites. Research into battery technology has focused for years on increasing energy density—how much energy can be stored in a given size and weight. This need became particularly acute during the rise of handheld devices, from industrial tools to mobile phones.

The demand for telecommunications satellites also emphasized the importance of battery weight, pushing technological advancements to prioritize battery capabilities. While labs worked on enhancing battery technology, rapid advancements in electronics technology continually increased energy and power requirements.
However, it was the emergence of electric vehicles (EVs) that truly underscored the critical role of batteries in providing greater range, reliability, and cost-effectiveness. For the EV market, factors like size, weight, and cycle life are paramount. Batteries, classified as primary (single-use, typically for long-term, low-power applications) and secondary (rechargeable), have seen a series of innovations aimed at achieving higher energy densities than ever before.

Presently, primary battery technology includes lithium metal, thionyl chloride (Li-SOCl2), and manganese oxide (Li-MnO2), suitable for applications lasting five to twenty years, such as metering, electronic toll collection, tracking, and the Internet of Things (IoT). Nickel-based (Ni-Cd, Ni-MH) batteries dominate rechargeable applications in telecom, aviation, and rail sectors. Meanwhile, lithium-ion (Li-ion) batteries lead the consumer electronics market and have expanded into electric vehicles. Notably, the volume of Li-ion batteries used in EVs now exceeds those used in mobile and IT applications combined. The evolution of lithium-ion batteries, driven by the growth in mobile phones, tablets, and laptops, has pushed for higher energy densities, directly impacting battery operating hours. Experts continually refine the technology, exploring new chemistries, design modifications, and raw material supply chain considerations, particularly addressing the challenges and costs associated with sourcing cobalt for Li-ion battery additives.

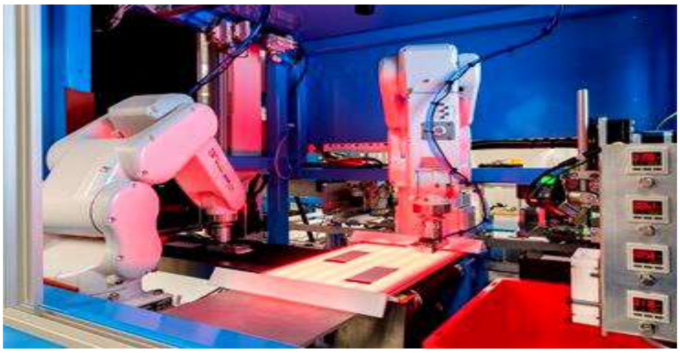
Energy density, measured in Watt-hours per kilogram (Wh/kg), is a crucial metric for evaluating battery performance. Currently, commercially available lithium-ion (Li-ion) batteries lead with the highest energy density, reaching up to 250-270 Wh/kg. In comparison, lead-acid batteries offer less than 100 Wh/kg, while nickel metal hydride batteries barely exceed 100 Wh/kg.
Alongside energy density, power density is equally important. Power density measures how quickly a battery can discharge or charge relative to its size, whereas energy density quantifies the total charge capacity. Batteries designed for high power density can discharge rapidly, contrasting with high-energy batteries that discharge over longer periods.
"Li-ion batteries exhibit exceptional power density," notes Joong Sun Park, technical manager at Solid State Technology. "Saft produces some of the world's highest power density Li-ion cells, used in applications like Joint Strike Fighter and Formula 1 racing, achieving up to 50 kW/kg."
Despite significant advancements over the past three decades, the performance of Li-ion batteries is approaching its limits due to material constraints and safety considerations, such as the risk of overheating and fire. Addressing safety concerns adds to the overall cost, as robust safety features must be integrated into battery systems.

Progress in mobile devices and electric vehicles has stretched battery technology to its limits. Innovations in battery design are now crucial to meet current energy demands.



Innovation is ongoing with alternative materials and battery chemistries like lithium-sulfur (Li/S), sodium, and magnesium-based designs, Park explains. These alternatives hold potential advantages in energy density and cost once they reach commercial viability, but they currently lag behind Li-ion in technological maturity. Achieving breakthroughs in materials and manufacturing processes is essential to compete with Li-ion. Despite promising developments, Li/S batteries, for instance, still face challenges in bridging the gap between academic research and practical production for commercial readiness.

The drive to reduce carbon emissions also spurs advancements in sustainable energy generation, such as solar and wind, coupled with energy storage solutions like batteries, Park emphasizes. This underscores the ongoing evolution in material selection, design improvements, and manufacturing techniques aimed at enhancing battery performance and sustainability. Innovations include solid-state batteries using materials like solid polymers, ceramics, and glass electrolytes, which eliminate toxic solvents used in traditional Li-ion battery



While lithium-ion technology has been dominant since its commercialization in the 1990s, there is a growing shift towards solid-state battery designs.

Doug Campbell, CEO and co-founder of Solid Power, Inc., notes, Lithium-ion has largely remained unchanged, with the same electrode combinations and minimal tweaks. The industry has pushed the technology to its limits.

Solid Power has explored various materials such as polymers, oxides, and sulfides in their research. They have chosen to advance sulfide technology, aiming to transition from liquid electrolyte batteries to solid-state batteries. This shift represents a departure from conventional designs but promises significant leaps in energy density capabilities. In liquid battery systems, metallic lithium forms dendrites that can compromise battery cycle life and safety. By replacing the liquid electrolyte with a solid-state electrolyte, which is safer and mechanically more robust, solid-state batteries can achieve higher energy densities without compromising safety.

Solid-state battery technology employs solid metal electrodes and a solid electrolyte. While the underlying chemistry remains similar to traditional batteries, solid-state designs mitigate issues like electrode leakage and corrosion, thereby reducing fire risks and lowering design costs by eliminating the need for extensive safety features. Furthermore, the use of a solid electrolyte enables a more compact battery size, reducing overall weight.

The most significant potential of solid-state batteries lies in their ability to surpass current energy density limitations. By utilizing metallic lithium, solid-state batteries theoretically could double the capacity of current Li-ion cells if implemented effectively. Metallic lithium offers ten times the capacity of standard carbon anodes used in current Li-ion batteries.

IS Shift to Solid-State Batteries.

The industry is currently transitioning to solid-state batteries for several key reasons. Firstly, traditional lithium batteries with liquid electrolytes have reached their theoretical limits in terms of electrode combinations, even with extensive design refinements aimed at increasing energy density.

In response to the growing electric vehicle (EV) market, there is a strong demand for higher energy densities, directly translating to increased vehicle range and overall battery longevity. The shift towards using high-capacity electrodes like solid lithium metal promises significant improvements of up to 50 to 100 percent in Watt-hour per kilogram. Moreover, replacing the volatile and flammable liquid electrolyte with a stable, solid material mitigates safety concerns such as thermal runaway, making solid-state batteries a safer option.

However, challenges remain, including identifying the most efficient materials and optimizing production techniques to reduce costs. Currently, solid-state batteries capable of competing in the market are mainly limited to small cells. The initial commercially available solid-state batteries are thin-film batteries, which are nano-sized and composed of layered materials serving as both electrodes and electrolytes. These batteries resemble conventional rechargeable batteries but are remarkably thin and flexible. In addition to their lightweight and compact nature, thin-film batteries offer higher energy density, making them suitable for smaller electronic devices such as pacemakers, wireless sensors, smart cards, and RFID tags.

The Future of Energy Storage

The future of energy storage is rapidly advancing, driven by the surge in EV sales and the demand for batteries that offer high energy density, long lifespan, and cost-effectiveness. The competitive landscape for solid-state batteries is becoming increasingly crowded, which is encouraging robust research and development efforts aimed at accelerating their market introduction. Currently, various materials and designs are being explored, showing promising progress.

With small cells already demonstrating the enhanced capabilities required from solid-state batteries, scaling up manufacturing processes for larger batteries is the next critical step. Several companies anticipate that these advanced batteries will hit the market within the next few years. As manufacturing capabilities expand, similar to the evolution seen with liquid electrolyte Li-ion batteries, ongoing technological innovations are expected to further enhance battery performance. This ongoing evolution will likely involve continual refinement of materials and design approaches, paving the way for significant advancements in battery capabilities in the years ahead.

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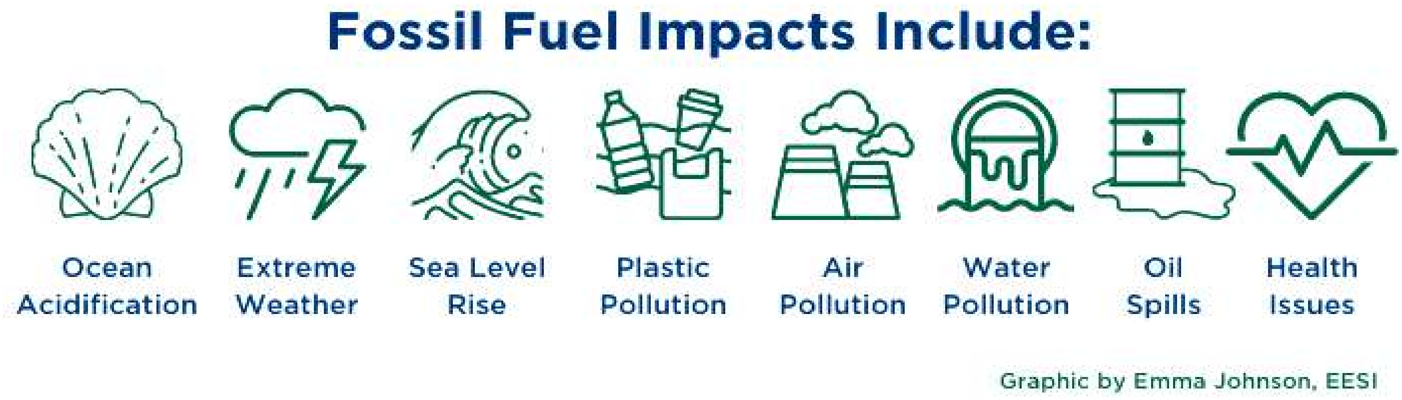
Fact Sheet on the Climate, Environmental, and Health Impacts of Fossil Fuels



The utilization of fossil fuels—coal, oil, and natural gas—incurs substantial climate, environmental, and health-related expenses that are not accounted for in market prices. These expenses, termed externalities, arise throughout the entire fossil fuel supply chain, encompassing extraction, transportation, refining, and combustion. This fact sheet offers an overview of various externalities linked to fossil fuel usage.

Ocean acidification results from the absorption of at least a quarter of the carbon dioxide emitted from fossil fuels by the ocean, altering its pH levels. This increased acidity hinders marine organisms' ability to form shells and coral skeletons. Over the past 150 years, ocean acidity has risen by 30 percent, posing significant threats to coral reefs, fisheries, tourism, and the economy.

According to the National Oceanic and Atmospheric Administration, climate change induced by fossil fuel combustion is contributing to more frequent and severe extreme weather events.

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These events, including wildfires, hurricanes, wind storms, flooding, and droughts, have caused disasters with costs exceeding one billion dollars each. From 2016 to 2020, the total cost of such extreme weather events in the United States was estimated at $606.9 billion.

Global warming driven by climate change is causing oceanic and atmospheric warming, leading to the melting of glaciers and land-based ice sheets. This phenomenon is contributing to a rise in global sea levels, which have increased by approximately 9 inches since the late 1800s. Consequently, coastal areas are experiencing more frequent flooding, destructive storm surges, and intrusion of saltwater. With 40 percent of the U.S. population residing along coastlines, it is projected that protecting these communities from sea level rise could cost $400 billion over the next two decades.

Fossil fuels carry significant environmental externalities, which include:

Air pollution: Fossil fuels emit hazardous air pollutants such as sulfur dioxide, nitrogen oxides, particulate matter, carbon monoxide, and mercury. These pollutants adversely affect the environment and human health (as discussed in the health section below). They contribute to acid rain, eutrophication (excessive nutrient levels harmful to aquatic ecosystems by reducing oxygen), crop and forest damage, and harm to wildlife.

Water pollution: Fossil fuel activities, from oil spills to fracking fluids, contribute to water pollution. Each fracking well uses between 1.5 million to 16 million gallons of water, and the resulting wastewater often contains toxic substances like arsenic, lead, chlorine, and mercury that can contaminate groundwater and drinking water.

Plastic pollution: Fossil fuels are crucial in plastic production, with over 99 percent of plastics derived from them. Globally, 300 million tons of plastic waste are generated annually, with 14 million tons ending up in the ocean, where it harms wildlife and pollutes the food chain. The plastic industry in the U.S. alone emits 232 million tons of carbon dioxide equivalent per year, and its greenhouse gas emissions are projected to exceed those of coal-fired power plants by 2030.

Oil spills: Fossil fuel extraction, transportation, and refining processes can lead to oil spills that damage communities and wildlife, destroy habitats, erode shorelines, and necessitate beach, park, and fishery closures. The 2010 BP Deepwater Horizon spill, the largest oil spill in history, released 134 million gallons of oil into the Gulf of Mexico. This disaster resulted in the loss of human lives, extensive damage to countless birds, turtles, fish, marine mammals, and plants, and cost BP $65 billion in penalties and cleanup efforts.

Phasing out fossil fuel subsidies	Eliminating subsidies could save taxpayers $35 billion over the next decade. For more details, see EESI's fact sheet on ending fossil fuel subsidies.
Increasing the social cost of carbon (SCC)	SCC estimates economic damages from carbon dioxide emissions, guiding federal policy on climate impacts assessment.
Federal clean electricity standard	Mandates utilities to sell a percentage of electricity from clean sources, promoting a gradual shift to cleaner energy on the electric grid.
Carbon pricing (e.g., carbon tax)	Sets a price on carbon emissions, requiring polluters to pay, or through cap-and-trade programs like the Regional Greenhouse Gas Initiative, reducing emissions.

Our skills span from developing future car designs to investigating driver safety, showcasing our wide-ranging expertise.

Systems Technology began its ground vehicle research with early projects for the former Bureau of Public Roads. Following the establishment of the Department of Transportation, our work continued in collaboration with the Federal Highway Administration, National Highway Traffic Safety Administration, and various private sector clients. Our research has centered on understanding driver and vehicle behavior, as well as enhancing driver and vehicle performance.

Specific studies have included investigating the impact of visibility on driver control and decision-making, assessing driver responses to traffic signals and signage, studying driver impairment from substances like drugs, alcohol, and fatigue, analyzing vehicle dynamics for improved driver and vehicle control, and conducting vehicle and tire tests to characterize vehicle behavior. In addition to these efforts, Systems Technology has developed valuable analysis tools, including comprehensive driver and vehicle simulation models, vehicle instrumentation solutions, and software for processing and interpreting static and dynamic test data.

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