We must decarbonize fast to combat climate change, but how can we achieve this goal when the US is in the middle of a divisive election and globally we're facing geopolitical conflicts, trade protectionism, weather disasters, increasing demand from developing countries building a middle class, and data centers in the U.S.? The U.S. Department of Energy is focusing on economically marginalized places in its clean energy expansion. The goal is to create a virtuous circle by providing benefits to disadvantaged communities, promoting workforce training partnerships, and encouraging well-paid union jobs. Several challenges need to be addressed, including policy, scientific, and engineering hurdles. Prasanna V. Joshi and Ernest J. Moniz discussed the importance of hydrogen as a zero-carbon fuel to reduce greenhouse gas emissions in industries like steel and fertilizer manufacturing. To achieve net zero emissions by 2050, ExxonMobil plans to use carbon capture and sequestration in natural gas-based hydrogen production. Industry is exploring burning ammonia directly in coal-fired power plants to extend the hydrogen value chain. Collaboration with MIT's ecosystem of breakthrough innovation will be essential to overcome these challenges. The energy transition is placing different demands on regions around the world, such as India, which aims to bring 300 gigawatts of zero-carbon capacity online by 2027. The goal is to provide reliable electricity to a population living in large cities and geographically remote villages. MIT's assets were on display at the conference, including young businesses like Form Energy and Noya, and innovative technologies such as Active Surfaces' lightweight material for solar photovoltaics. LAES technology holds promise as means of providing long-duration storage for power grids dominated by intermittent renewable sources. A team of researchers from MIT and NTNU developed a model to evaluate the economic viability of liquid air energy storage (LAES) systems. They found that under certain scenarios, LAES could be economically viable in various locations, particularly with subsidy policies on capital expenses. Liquid Air Storage’s Economic Viability Depends on Policy Incentives, Not Technical Efficiency alone While liquid air storage may not be economically viable today, researchers are exploring its potential as a grid-scale energy solution. A study by Cetegen found that liquid air storage has a lower levelized cost of storage (LCOS) than lithium-ion batteries and pumped hydro. However, the LCOS varied depending on location, suggesting that reporting a single LCOS for an energy storage technology may not provide the full picture. Cetegen is now adapting her model to calculate the net present value (NPV) and LCOS for energy storage using lithium-ion batteries. Data centers are projected to consume nearly 1,050 terawatts of electricity by 2026, surpassing Japan's current ranking on the global list and joining Russia in fifth place. While not all data center computation relies on generative AI, this technology has significantly driven up energy demands. "We can't meet the demand for new data centers sustainably," says Bashir. The majority of electricity powering these facilities will likely come from fossil fuel-based power plants. Generative AI training processes require immense amounts of electricity and generate substantial carbon emissions. For instance, scientists estimated that OpenAI's GPT-3 training alone consumed 1,287 megawatt hours of electricity (enough to power about 120 average U.S. homes for a year), generating approximately 552 tons of carbon dioxide. However, the environmental impact doesn't stop at training; inference - the process of using trained models - also significantly contributes to energy consumption. A ChatGPT query consumes about five times more electricity than a standard web search. "As users, we often don't think much about it," notes Bashir. This lack of awareness and information makes it difficult for users to cut back on their generative AI usage. Unlike traditional AI, where data processing, model training, and inference split energy usage fairly evenly, generative AI's electricity demands are expected to be dominated by inference as these models become increasingly ubiquitous. Furthermore, the shelf life of generative AI models is short due to rising demand for new applications, often leading to wasted energy from previous versions. Data centers' water consumption also has environmental implications. Chilled water used for cooling absorbs heat from computing equipment and requires substantial amounts of water - approximately two liters per kilowatt hour of energy consumed. "Just because it's called 'cloud computing' doesn't mean the hardware isn't physically present," Bashir emphasizes, highlighting data centers' direct impacts on biodiversity through water usage. The environmental implications extend beyond power consumption to the manufacturing process of computing hardware. The production of GPUs, specifically, has a significant carbon footprint due to complex fabrication processes and emissions related to material transport and raw material extraction. As the number of GPUs shipped to data centers continues to increase (3.85 million in 2023), the industry is on an unsustainable path. However, there are steps towards promoting responsible development of generative AI that aligns with environmental objectives. This involves a comprehensive assessment of environmental and societal costs alongside benefits. "We need a more contextual understanding of these implications," says Olivetti. A thorough evaluation will enable more informed decision-making regarding the development and deployment of generative AI technologies.The elusive goal of fusion power has proven to be a daunting challenge for researchers at MIT, despite decades of efforts. Hartwig's drive to tackle this complex problem stems from his passion for overcoming difficult obstacles, which he believes is a key motivator for many in the field. Hartwig's journey into fusion research began when he faced a significant setback - the Department of Energy announced plans to terminate funding for the Alcator C-Mod tokamak, a major experiment that Hartwig needed to complete his PhD. This scare only strengthened his resolve, and he took a faculty position at MIT in 2017 to continue working on fusion. One crucial aspect of fusion research is the development of high-temperature superconducting magnets, which enable reactors to be smaller, cheaper, and faster. Hartwig's work with Professor Dennis Whyte's class led to the creation of Commonwealth Fusion Systems (CFS), a company that aims to build commercial-scale fusion power plants. The progress made by CFS has been significant, attracting over $2 billion in investments and exceeding $8 billion in private investment. The industry's outlook has shifted, with fewer people joking about the 30-year delay for achieving fusion power. Hartwig's path to becoming a leading expert in fusion research was not traditional. He initially studied biomedical engineering due to his brother's influence but later discovered his passion for physics and applied physics. Hartwig took time off after graduate school to pursue his interests, including competitive cycling, which helped him mature and refocus. Upon returning to academia, Hartwig joined the Department of Nuclear Science and Engineering at MIT, where he worked on designing nuclear fusion power plants under Professor Whyte's guidance. This project sparked a promising direction for the field, leading to the establishment of CFS. The increased demand for fusion research has been evident, with many graduate students now interested in pursuing careers in this area. Hartwig attributes this surge in interest to the growing excitement about the possibilities offered by fusion power, which he hopes will lead to accelerated progress and learning in the field. Form Energy's iron-based battery technology is poised to revolutionize the field of energy storage, enabling widespread adoption of renewable energy sources by providing a cost-effective and reliable solution for long-duration energy storage. Form Energy's Iron-Air Battery Solution Paves Way for Decarbonized Grids The world's transition to renewable energy sources requires innovative solutions to manage intermittent power generation. Form Energy, a company co-founded by physicist Chris Chiang and engineer Juan Jaramillo, has developed an iron-air battery technology that could revolutionize the way we store energy. By harnessing the power of sulfur, sodium, water, and air, their battery modules can provide cost-competitive, firm electricity in resource-abundant locations. The development of a membrane that separates crude oil components based on their molecular size could significantly reduce energy consumption in the process. This new filtration system uses polymers that are commonly used for water desalination, but have been modified to be more effective at separating hydrocarbons. The researchers found that by changing the bond between the monomers and adding a triptycene molecule, they were able to create a membrane with pores that allowed hydrocarbons to pass through quickly while filtering out smaller compounds. According to the team leader, Taehoon Lee, this new approach has the potential to reduce energy consumption in oil fractionation by up to 90 percent. The current process of fractionating crude oil using heat-driven methods accounts for only 1 percent of global energy use, and this new method could revolutionize the industry. The researchers have successfully tested their membrane on a mixture of toluene and triisopropylbenzene (TIPB), achieving a concentration of toluene 20 times greater than its concentration in the initial mixture. This demonstrates the effectiveness of the new filtration system in separating components of crude oil based on their molecular size. The development of this membrane is an important step toward reducing industrial energy consumption, and it has the potential to transform the way hydrocarbons are separated and processed. The researchers' imaginative approach to using interfacial polymerization and hydrophobic monomers has led to a membrane with high permeance and excellent selectivity. The researchers developed a membrane that could efficiently separate heavier and lighter compounds by their molecular size. They tested it with an industrially relevant mixture of naphtha, kerosene, and diesel, finding it to be effective. If adapted for industrial use, the filter could generate higher concentrations of desired products at each step. Artificial intelligence is transforming power systems, enabling faster grid optimization, reducing carbon emissions, and accelerating materials discovery for clean applications. Industry leaders emphasized the need to balance rapid AI deployment with environmental impacts, while exploring novel approaches to integrate renewable sources with existing infrastructure. As the energy transition gains momentum, participants at a symposium highlighted MIT's central role in developing solutions to the AI-electricity challenge. With growing concerns over climate change, researchers are rethinking power supply for computing facilities, prioritizing carbon intensity, reliability, and cost. If we don't change our ways for a better future, we'll still have major problems with climate change. Our approach must include transformation, intervention, and adaptation strategies. Switching to a decarbonized electricity system is one part of the puzzle. We're seeing a shift towards solar, wind, nuclear, hydropower, and geothermal energy, but new technologies like advanced geothermal and fusion are still down the pipeline. Carter said that using carbon-free electricity can electrify everything we can, including the industrial sector. However, this is a big area for transformation because most industries use fossil fuels now. Thermal energy is less efficient than electricity, so we need to find ways to replace heat with electricity-driven strategies like electrolysis, plasmas, LEDs for photocatalysis, and joule heating. The transportation sector also needs electrification, but it's not as easy for heavy-duty vehicles. The solution is carbon-neutral fuels for aviation and shipping. These fuels must come from non-fossil sources to reduce CO_2 emissions. Next, we need to intervene with carbon dioxide removal methods. This involves capturing CO_2 from industrial plants, storing it in underground aquifers, and then using commercial utilization to accelerate sequestration. We can also convert CO_2 into carbonates that can be used in building materials. Another form of intervention is solar geoengineering, also known as SRM. This involves injecting particles into the atmosphere to reflect sunlight and cool the Earth. Carter says we should understand what this technology does because it's a global security issue. The transportation sector poses a significant challenge in achieving global carbon neutrality. A recent study by MIT researchers has shed light on the impact of zero-emission trucks on their energy storage requirements and operational revenue. The multivariable model outlined in the paper equips fleet owners and operators with the tools to make informed decisions about transitioning to battery-electric or hydrogen fuel cell heavy-duty trucks. However, this transition is hindered by technical challenges, such as the need for significant energy storage, infrastructure limitations, and high costs associated with new technologies. The study's findings suggest that a combination of government incentives and corporate investment will be necessary to drive the adoption of zero-emission trucks. MIT Launches Comprehensive Plan to Tackle Climate Change with Partnerships and Innovation A collaborative effort between the MIT Climate and Sustainability Consortium, Zero Impact Aviation Alliance, and various researchers aims to reduce emissions and develop sustainable solutions for the transportation sector. Developed by a team of experts led by Danika MacDonell and Florian Allroggen, the Geospatial Decision Support Tool provides critical insights into freight flow densities, costs, and infrastructure requirements by region. This cutting-edge technology empowers fleet operators to make informed decisions and drive positive change in the industry. Industry leaders have taken notice of this initiative, with General Motors and Hyundai recently announcing a partnership to explore collaborative opportunities across key strategic areas, including clean energy. Evelyn Wang, MIT's first vice president for energy and climate, is leading the Institute's efforts on this front. A mechanical engineering professor with expertise in water extraction and energy solutions, Wang has brought her problem-solving experience and optimism to the task of tackling climate change. Wang recognizes the importance of partnerships in driving progress on climate issues, stating that "tackling climate change requires a lot of partnerships." She aims to build connections between MIT, corporate allies, startups, government, communities, and other organizations to amplify the impact of their work. As vice president for energy and climate, Wang is committed to scaling up existing innovations, identifying new breakthroughs, and leveraging campus community input to drive progress. Her research focus extends beyond water extraction, with a current emphasis on energy and desalination technologies. Wang's experience in leading early-stage R&D projects and her tenure as director of the U.S. Department of Energy's Advanced Research Projects Agency-Energy have prepared her for this role. She is now focused on engaging researchers, holding community workshops, and building partnerships to drive meaningful change. The faculty at MIT are actively engaged in climate-related research, a fact that Wang finds particularly striking. According to her, the challenge lies not in identifying areas of improvement but rather in leveraging their unique expertise to create a more substantial impact than the sum of its individual components. This is an area of focus for Wang, who aims to facilitate collaboration and accelerate innovation in this field. Wang's own background at MIT serves as a significant strength in her role, with over two decades spent on campus. She holds multiple esteemed faculty positions, including Professor of Engineering, and has previously served as the head of the Mechanical Engineering department. Her personal connection to the institution is deep-seated, with both parents meeting as graduate students and several family members graduating from MIT. As vice president for energy and climate, Wang brings a sense of urgency to the issue, coupled with an unwavering optimism that innovation can address society's needs. This attitude is reflective of her perception of MIT's mission-driven nature, where individuals come together to tackle real-world challenges. Wang views this approach as not only a challenge but also a generational opportunity, allowing her to design a more sustainable and resilient world. Several examples illustrate the potential impact of research conducted at MIT, such as the creation of the Schmidt Laboratory for Materials in Nuclear Technologies or the development of clean ammonia. These breakthroughs suggest that the future can be shaped through collective efforts, providing Wang with optimism about the possibilities.