The Research Layout and Key Strategies of Digital Decarbonization in the United States

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To address the impacts of increasingly frequent global climate anomalies, the United States has actively promoted net-zero carbon emission reforms in recent years. This includes key legislative acts and executive orders supporting policies, as well as the development of cutting-edge technologies. Policy initiatives, such as the PROVE IT Act, which conducts industrial carbon audits, and the Clean Competition Act (CCA), which protects domestic industry and export competitiveness while reducing the risk of carbon leakage, are examples of this approach.

In terms of forward-looking technology development, to understand the U.S. government's research layout on digital decarbonization, this article will use the keyword "digital decarbonization" to search relevant research projects within the National Science Foundation (NSF) and the Advanced Research Projects Agency-Energy (ARPA-E). The goal is to analyze the trends and key strategies of the U.S. in this field. Five major trends in digital decarbonization research have been identified:

1. **Adoption** of machine learning: Machine learning is employed to assist in improving equipment, developing materials, optimizing design, and validating tests. The goal is to support material exploration and development, equipment performance optimization, and low-carbon design in industrial processes. This helps reduce energy consumption and improve efficiency, promoting diverse development and application of digital decarbonization technologies.

2. **Establishment of digital platforms for carbon management**: These platforms monitor energy use and carbon emissions, quantify carbon emissions during production, and enhance environmental management capabilities. This includes achieving carbon measurement, carbon management, and carbon utilization by addressing decarbonization at various stages, improving energy efficiency, and reducing greenhouse gas emissions. For example, performance improvements in equipment such as digital energy-saving pumps can reduce operational downtime or equipment failures.

3. **Promotion of digital twins to enhance decarbonization**: Digital twins, combining

virtual and physical technologies, are used for factory monitoring, early warning, diagnostics, and forecasting. This indirectly improves efficiency and reduces energy consumption, enabling efficient factory operations and reducing greenhouse gas emissions. Digital twins are also used in climate-adaptive building design, vertically integrating greenhouse gas emissions related to infrastructure operations and systematically quantifying carbon emissions to minimize energy demand.

4. **Development of green chips**: By advancing chip materials or designs, computing efficiency is improved, and energy consumption is reduced. For example, hybrid organic electro-optical materials developed for communication systems enhance computational performance. Neuromorphic chip designs inspired by the brain, which mimic the flexibility, robustness, and efficiency of biological intelligence, help reduce energy consumption in information processing.

5. **Creation of digital infrastructure**: The goal here is to foster environmentally sustainable digital infrastructure, focusing on improving data processing efficiency in response to the growing computational demands that have significant environmental impacts. This includes efforts such as decarbonizing data centers, creating sustainable cloud infrastructures, and developing sustainable edge data centers.

By synthesizing the research trends in digital decarbonization in the U.S., the primary objective is to introduce various innovative technological applications that accelerate decarbonization across industries and enhance the application capabilities of digital technologies. This helps industries increase production efficiency, reduce costs, and improve overall environmental benefits.