NREL to lead one exascale computing project, support three others

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Scientists at the Energy Department's (DOE) National Renewable Energy Laboratory (NREL) will lead an effort to model the complex and turbulent flow of wind through large wind plants as part of DOE's Exascale Computing Project (ECP), which is gearing up U.S. computational capabilities to prepare for the next generation of supercomputers. NREL will also provide support to three projects related to combustion science, urban systems, and power grid dynamics.

Exascale refers to high-performance computing (HPC) systems capable of at least a billion billion calculations per second, or 50 to 100 times faster than the nation's most powerful supercomputers in use today. The ECP projects target advanced modeling and simulation solutions to specific challenges supporting key DOE missions in science, clean energy, and national security. Because designing an exascale computer will require a significant change from current supercomputer architectures, scientific applications that run on today's systems may also need to be reconfigured to take advantage of exascale systems.

The wind plant modeling that NREL is leading builds on the laboratory's previous work to develop three-dimensional models of wind flow through a simplified wind farm. That work has already yielded benefits, showing that coordinated wind farm controls can increase the total power output by as much as 4%-5%.

The new project, led by NREL in collaboration with scientists at Sandia National Laboratories (SNL), Oak Ridge National Laboratory, and the

University of Texas-Austin, aims to expand that approach to wind farm scenarios consisting of 100 or more megawatt-scale wind turbines sited within a 10 kilometer-by-10 kilometer area with complex terrain. The project will build on the SNL-supported, open-source Nalu code for computational fluid dynamics, which is the numerical approach to modeling fluid flow. Fully implemented, the project would require simulations with approximately 100 billion grid points.

"This project will make a substantial contribution to advancing wind energy," said Steve Hammond, NREL's Director of Computational Science and the principal investigator on the project. "It will advance our fundamental understanding of the complex flow physics of whole wind plants, which will help further reduce the cost of electricity derived from wind energy."

The challenge is to build a predictive simulation capability that can be effectively scaled up to run on an exascale HPC system. The approach will be to run more limited simulations on today's petascale computers, such as NREL's [Peregrine](link) and other DOE HPC systems, while validating the accuracy and demonstrating that the software can be scaled up to run on more than 500,000 cores—either central processing units (CPUs) or graphics processing units (GPUs). The ultimate goal is to create a predictive wind farm simulation capability that runs on an exascale-class computer by 2022.

"A fully blade-resolved model of a single turbine would require the full computing capability of today's fastest computers. Detailed models of entire wind plants are beyond our current capabilities," Hammond said. "This project aims to develop exascale applications that can be ready to run once the exascale computing capability becomes available."

NREL is also participating in these [four-year projects](link):

"Transforming Combustion Science and Technology with Exascale Simulations," led by Sandia National Laboratories, will use computer simulations to design high-efficiency, low-emission combustion engines and gas turbines to reduce emissions and improve fuel efficiency.

"Multiscale Coupled Urban Systems," led by Argonne National Laboratory, will retrofit and improve urban districts with new technologies, knowledge, and tools.

"Optimizing Stochastic Grid Dynamics at Exascale," led by Pacific Northwest National Laboratory, will develop the formulation, algorithms, and software to optimize electric system expansion planning that includes detailed operational models of the grid, accounting for the uncertainty and variability of renewable energy generation, the dynamics of generators, and transient constraints.

The ECP's multi-year mission is to maximize the benefits of high performance computing for U.S. economic competitiveness, national security, and scientific discovery. In addition to applications, the DOE project addresses hardware, software, platforms and workforce development needs critical to the effective development and deployment of future exascale systems. The ECP is sponsored by DOE's Office of Science and the National Nuclear Security Administration.

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