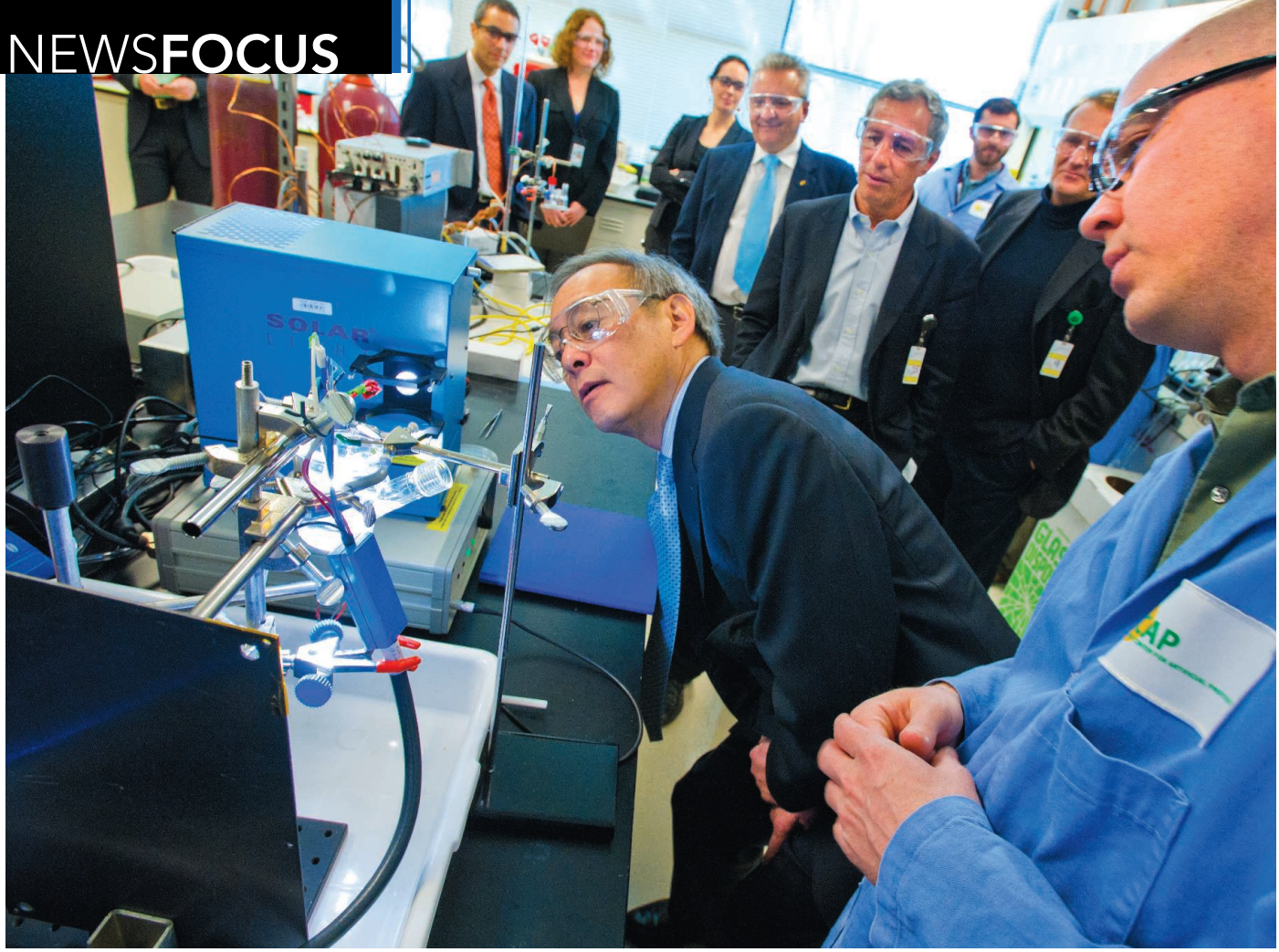

Hubs Aim to Reinvent DOE Research Culture

The U.S. Department of Energy has funded a series of energy innovation hubs to tackle big energy challenges from start to finish. But their future is uncertain

EIGHT NUCLEAR ENGINEERS SIT IN HIGH-backed leather chairs, their laptop computers perched on sleek wood consoles. The lights are so low that the corners of the room fade to black. Up front, a roomwide video screen shows a half-dozen other researchers from locations around the country. A cryptic conversation rattles on: "Rod, we have to be careful. Right now the Cobra to de Novo isn't even using DTK."

Welcome to the Consortium for Advanced Simulation of Light Water Reactors (CASL) at Oak Ridge National Laboratory in Tennessee, one of five "energy innovation hubs" launched by the Department of Energy (DOE) to tackle tough problems. The researchers participating in the virtual meeting at CASL are scrolling through a vast list of tasks as they integrate different computer programs for simulating the inner workings of nuclear reactors so that utilities can run them more efficiently.

The brainchildren of Steven Chu, the Nobel Prize–winning physicist who stepped down last month as secretary of energy, the hubs are a bold experiment in how DOE does research. Modeled after the Manhattan Project that built the atomic bomb and the famed Bell Labs, the hubs aim to make the sprawling and notoriously bureaucratic agency more nimble and responsive. Each would focus on a single problem, assemble "under one roof" all the scientists and engineers needed to tackle everything from basic research through technological development, and take a free-wheeling approach to hammer out a solution as fast as possible.

In 2009, as soon as he became energy secretary, Chu announced plans to create eight hubs. To date, DOE has launched five, funding each for $122 million over 5 years with the possibility of a 5-year renewal. In 2010, in addition to CASL, it established hubs that focus on generating fuel from sunlight through artificial photosynthesis and reducing energy consumption in buildings. In recent months, DOE has launched hubs to create far better batteries and to head off shortages of materials. And DOE's proposed budget for 2014 requests money for a sixth hub on electrical systems such as the power grid.

The problem-oriented approach draws plaudits from researchers and some policymakers in Washington, D.C. "The hub is exactly what DOE should be doing," says Charles Dismukes, a physical chemist at Rutgers University, Busch Campus, in Piscataway, New Jersey. A Republican Senate staffer agrees: "I think you're going to see an expansion of these, and the traditional

CREDIT: ROY KALTSCHMIDT

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Check it out. Then–Energy Secretary Steven Chu visited the Joint Center for Artificial Photosynthesis in April 2012.

[DOE research] program may stagnate as a result."

Before that can happen, however, the hubs will have to prove their worth at a time when budgets are likely to be tight. Evaluating them will not be easy, in part because they widely vary in the ways that they are organized and the types of problems that they are tackling. For example, only one of the five strives to be a physical center of activity; the rest are widely distributed collaborations. In fact, the hubs vary so much that it's difficult to say exactly what a hub is. And some see a risk that, now that Chu is gone, the hubs could be subsumed into the department's existing bureaucracy and their independence compromised.

Breaking down the stovepipes

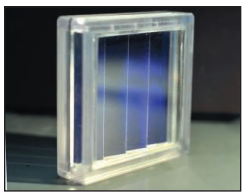
To understand what a hub is supposed to be, it helps to understand how DOE is structured. Sometimes called the Department of Everything, DOE has a $24.4 billion annual budget and comprises a dozen different offices and agencies, such as the National Nuclear Security Administration, which safeguards the United States' nuclear weapons, and the Office of Energy Efficiency and Renewable Energy (EERE), which develops clean energy technologies. An office may be divided into programs, such as the $1.6 billion Basic Energy Sciences (BES) program within the $4.7 billion Office of Science.

DOE has a reputation for being badly "stovepiped," meaning that the various offices and programs poorly communicate with one another. For example, in theory the BES program should yield breakthroughs in basic research that the EERE program then develops through its applied research. In practice, "BES does its thing and then they throw it over the transom and hopefully it hits somebody at EERE in the head," says William Madia, vice president at Stanford University for DOE's SLAC National Accelerator Laboratory in Menlo Park, California, a national lab mainly supported by BES.

The hubs aim to break down the barriers between basic and applied research. Chu shaped the concept by calling on his experience at Bell Labs, the research wing of the AT&T phone company that from the 1920s through the 1990s produced technologies ranging from the transistor to the laser. Chu did his Nobel Prize–winning work there,

HUBS CAPSULES

JOINT CENTER FOR ARTIFICIAL PHOTOSYNTHESIS (JCAP)

Locations	Founded	Goal	Prospects
California Institute of Technology in Pasadena and Lawrence Berkeley National Laboratory in California	2010 	Produce affordable, durable, and efficient solar cell that generates hydrogen fuel from sunlight and water.	The most hublike hub, JCAP strives to keep all its research literally under its two roofs. To reach their goal, researchers must overcome numerous challenges in basic research.

CONSORTIUM FOR ADVANCED SIMULATION OF LIGHT WATER REACTORS (CASL)

Locations	Founded	Goal	Prospects
Oak Ridge National Laboratory, Tennessee	2010	Create detailed 3D simulations of existing reactors to enable utilities to improve efficiency.	CASL has already produced new insights into reactors. Success will require the Nuclear Regulatory Commission to approve the new simulations in licensing new fuel designs and fuel cycles.

ENERGY EFFICIENT BUILDINGS (EEB)

Locations	Founded	Goal	Prospects
Philadelphia, Pennsylvania Lead institution: Pennsylvania State University	2010	Improve energy efficiency of buildings in the Philadelphia metropolitan area by 20% by 2020.	As well as tackling technological problems, EEB researchers study the economic and regulatory issues affecting building efficiency. Some observers question whether that diverse approach is appropriate for a hub.

JOINT CENTER FOR ENERGY STORAGE RESEARCH (JCESR)

Locations	Founded	Goal	Prospects
Argonne National Laboratory, Illinois	2012	Develop within 5 years a battery that holds five times as much energy as a standard lithium ion battery at one-fifth the cost.	JCESR researchers say that they ought to be able to meet their crisply defined goal. But turning theory into reality in 5 years will be tough.

CRITICAL MATERIALS INSTITUTE (CMI)

Locations	Founded	Goal	Prospects
Ames National Laboratory, Iowa	2013	Head off shortages of key elements such as rare earth metals by finding replacements and better means of extraction and recycling.	CMI leaders say that they seek to become a standing resource for those in the field. Some observers question if that fits with the hubs' problem-oriented approach.

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and he says the lab succeeded because it let scientists and engineers quickly hash things out for themselves.

"The managing scientists and engineers were the bosses," Chu says. "Unlike a 3-year grant where you write a proposal and it takes a year to get funded, at Bell Labs if I had an idea I'd go to my boss or my boss's boss and get a yes or no in days or weeks."

As at Bell Labs, a hub is supposed to bring together all the people and resources needed to perform everything from the basic research and development to demonstration and deployment of a prototype solution. "The distinctive signature of the hub is that it goes from basic research all the way through to deployment all under one roof," Madia says. "You can't find that kind of activity when you look at the DOE stovepipes."

The target areas for the hubs have been chosen by top DOE officials, including Chu himself. Teams then submitted proposals and competed for each hub, with the proposal detailing a team's approach to the problem.

Cyber center. Video conferencing links researchers at the widely dispersed Consortium for Advanced Simulation of Light Water Reactors.

The archetypal hub

No hub embodies the center-of-action concept used at Bell Labs more closely than the Joint Center for Artificial Photosynthesis (JCAP). Headquartered at the California Institute of Technology (Caltech) in Pasadena and funded by the BES program, JCAP (pronounced J-cap) aims to create a technology that could ease both the world's looming energy crunch and climate change caused by burning fossil fuels. "We want to have something that you can hold in your hand that will produce fuel from sunlight in a way that humans haven't done before—with no wires and no microbes," says Nathan Lewis, a chemist at Caltech and JCAP's founding director and chief scientist.

The basic idea of "solar fuels" isn't new. Plants store solar energy in sugars through photosynthesis, so a refinery that generates ethanol from corn creates fuel from sunlight. JCAP researchers aim for something more direct—using solar energy to split water and generate combustible hydrogen gas. That can be done in the lab by, for example, using a wafer of silicon plated with platinum on one side and iridium on the other. Using solar energy captured by the silicon, the iridium catalyzes the breakup water into oxygen molecules, hydrogen ions, and electrons, while the platinum combines the electrons and ions into hydrogen molecules. Other approaches use different catalysts.

But none of those approaches is ready for the real world. For a solar-fuels industry to flourish, its core technology must be efficient, durable, and cheap. No existing technique nails all three requirements, says Carl Koval, an electrochemist at Caltech and JCAP's director. The platinum and iridium scheme is efficient and robust, for example, but iridium is rare and expensive. JCAP's goal is a cheap, durable cell that is 10 times as efficient as photosynthesis.

As the hub concept stipulates, JCAP researchers grapple with every aspect of the problem, breaking it into eight distinct projects. Interconnected groups strive to identify new catalysts and light-capturing materials, make sure they'll work together, integrate them into structures sculpted on the nanometer-scale, and design the macroscopic cell. Some of JCAP's goals are wildly ambitious. Researchers plan to characterize a million catalysts per day using a modified inkjet printer to print tiny dollops of the materials on glass slides. That would be more catalysts in 1 day than have been characterized in history, Lewis says.

Perhaps most striking is the enthusiasm with which JCAP officials embrace the "one roof" concept. JCAP leaders say that their biggest organizational challenge is to prevent JCAP from becoming just another university research center. William Royea, a chemist and JCAP's assistant director for strategy and communications, characterizes such a center as "a confederation of research projects in which everybody goes off and does whatever they want." JCAP leaders see physical proximity as the best means to avoid that loss of focus.

In particular, JCAP leaders want to prevent scientists from viewing the hub as just a source of funding for work that they're already doing in their own labs. To keep researchers focused on building the device, JCAP officials insist that they work in JCAP's cozy building. "If you're on JCAP, you're here every day. You're in the building," Lewis says. (JCAP actually has two buildings, with a northern branch at Lawrence Berkeley National Laboratory in California. However, its leaders note that Bell Labs also had multiple campuses.)

The flow of money also follows the Bell Labs' model. Funding goes not to individual principal investigators but to the eight project leaders who distribute it as they see fit.

Virtual centers

Although JCAP strives to be a center of activity, the other hubs are extended collaborations. For example, CASL comprises 10 institutions including DOE's Idaho National Laboratory in Idaho Falls; the Electric Power Research Institute (EPRI) in Palo Alto, California; and Westinghouse Electric Company. Most researchers visit Oak Ridge only every other month. "I love living here," says Douglas Kothe, a nuclear engineer at Oak Ridge who leads CASL. "But a lot of people don't and a lot of people won't. So our one-roof model is to aggressively deploy virtual-collaboration technology."

That's fine, observers say, because the cost of moving people and equipment could easily consume all the money that the hub receives from DOE. The real issue, they say, is whether a hub tackles the right kind of problem—one big enough to require a hub's resources, but not so big that it can't be solved in 5 years. By all accounts, CASL has found just such a problem: simulating the inner workings of the nuclear reactors in service today.

Funded through DOE's $720 million Office of Nuclear Energy, CASL is an attempt to play catch-up. The nuclear industry pioneered the use of simulations, Kothe says. But the United States has not broken ground for a new nuclear power plant since 1977, and as the nuclear industry stagnated, so did the simulations. "This field is a couple of decades

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behind" the automotive and aerospace industries in using simulations, Kothe says.

Still, such simulations are crucial for demonstrating to the Nuclear Regulatory Commission (NRC) that any changes to a reactor's design or operations will be safe. The 104 U.S. reactors now run at 92% of capacity, up from less than 80% 20 years ago, says John Gaertner, a nuclear engineer and CASL member from EPRI. To improve efficiency and reduce costs, utilities would like to further increase power levels, the length of fuel cycles, and the extent to which fuel is depleted, or "burn-up." Current simulations largely rely on data from reactor tests to make semiempirical predictions, says Daniel Ingersoll, a nuclear engineer with NuScale Power in Portland, Oregon, who does not work on CASL. That limits how much plant owners can change designs and operations, he says.

CASL aims to produce 3D simulations that more fully capture the underlying physics and chemistry, says Paul Turinsky, a nuclear engineer from North Carolina State University in Raleigh and CASL's chief scientist. Current 2D simulations track the flow of cooling water around the fuel rods in the reactor's core at hundreds of points; CASL's simulations will track it at a billion points. Turinsky says that CASL's simulations will also encompass the tricky interactions between the radiation emanating from the fuel rods, the flow and heating of the water around the rods, and the effects of the radiation on materials such as the rods' metal cladding.

CASL is leading the other hubs in generating results, observers say. To ensure that their work is practical, CASL researchers are also analyzing operational challenges facing reactors. One is the buildup of deposits known as CRUD—for their historical name, Chalk River Unidentified Deposits—on the fuel rods, which can distort the rods' power output. CASL researchers have already predicted a CRUD pattern that was later detected on rods. "We consider that a major advance," says William Martin, a nuclear engineer and CASL member from the University of Michigan, Ann Arbor.

CASL researchers hope that industry will use their simulations to improve the design of fuel assemblies and fuel cycles. Developing the simulations is too costly for industry alone, says Zeses Karoutas, a nuclear engineer and CASL member with Westinghouse in Columbia. "Industry can't put together the kind of funding that's needed," he says. "The only way to do it is to leverage the national labs and the universities."

Soft focus

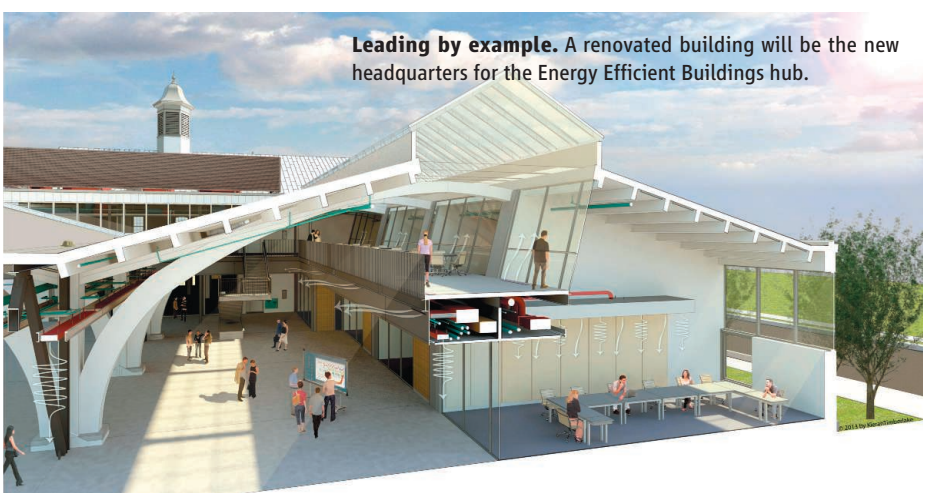
Some hubs are not focusing on a specific problem, an approach that has created some controversy. The Energy Efficient Buildings (EEB) hub in Philadelphia, Pennsylvania, which is mainly funded by EERE, aims to improve energy efficiency in area buildings by 20% by 2020. Buildings soak up 40% of the energy used in the United States, says James Freihaut, a fuel scientist at Pennsylvania State University (Penn State), University Park, and chief scientist for EEB. So if implemented nationwide, such an improvement would save massive amounts of energy.

Buildings have become only marginally more efficient in recent decades, even though the efficiency of subsystems such as heating, air conditioning, lighting, ventilation, and electrical power have improved by larger amounts, Freihaut says. That disparity arises because builders do not consider how the various subsystems will interact, he says. "We're trying to transform the building industry as a whole into a system provider," he says.

way membranes to draw moisture out of a building or building materials whose capacity to hold heat changes with temperature, energy use could drop by between 30% and 50%, Freihaut predicts.

However, improving building efficiency is not a single well-defined technological problem, but rather a raft of various technological, economic, and regulatory issues. For example, the Philadelphia City Council drew upon one of EEB's studies for an ordinance that requires the owners of commercial buildings bigger than 4700 square meters to publicly report a building's water and energy consumption. The law, passed in June 2012, is supposed to give tenants a clearer idea of their energy costs and owners an incentive to make buildings more efficient.

EEB's work is focused less on developing new technologies and more on persuading builders to adopt ones that already exist. "We actually don't want to be too much on the leading edge because building owners are naturally conservative," says Laurie Actman, an engineer at Penn State and deputy director of EEB.



Leading by example. A renovated building will be the new headquarters for the Energy Efficient Buildings hub.

CREDIT: COURTESY OF KIERANTIMBERLAKE

To do so, EEB researchers are developing computer modeling tools to predict how different combinations of specific subsystems will interact. The need for such tools became apparent when EEB researchers went to retrofit their current headquarters, an old building in Philadelphia's Navy Yard, Freihaut says. Three different consulting firms gave entirely different assessments of what needed to be done, he says.

Using their own building, EEB researchers are also studying how many measurements of temperature, humidity, air flow, electricity use, and other factors are needed for a building to be "self-aware" enough optimize its energy consumption. With foreseeable advances in materials, such as one-

All that work may be worthy, but some Washington insiders question whether it requires a $122 million hub. In fact, multiple sources on Capitol Hill say that EEB's future is uncertain. "We have serious concerns about the building hub," says a staffer for the Democratic majority in the Senate. "If this doesn't turn around in the next few months in terms of clarifying what we're getting for our investment, you may see some action."

The same issue of focus has come up with regard to one of the two latest hubs. One of them seems to neatly fit the hub model in having a crisply defined technological goal. In November, researchers at Argonne National Laboratory in Illinois won the competition for a hub to develop far better bat-

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teries. The Joint Center for Energy Storage Research (JCESR) aims to produce within 5 years a battery that can hold five times as much energy as a standard lithium ion battery and can be made for one-fifth the cost.

In contrast, the Critical Materials Institute (CMI) at Ames Laboratory in Iowa, which launched in January, will tackle the complex question of how to ease shortages of vital elements such as the one that arose in 2009 when China threatened to stop exporting neodymium, europium, and other rare earth metals. CMI researchers will take a four-pronged approach, doing the basic materials science to find ways of replacing or reducing the use of key materials, exploring better ways to extract materials from ore, pursuing advanced recycling, and trying to predict shortages.

In doing so, however, CMI researchers seek to solve not a single technological challenge, but rather to meet a variety of challenges as they arise. "What we are seeking to develop is a resource—the SWAT team for materials shortages," says Alexander King, a materials scientist and director of Ames lab and CMI. That description raises some eyebrows in Washington. "The original notion of a laser focus on a specific problem that you'd know whether you'd solved it or not is totally unclear on that one," says one Republican House of Representatives staffer.

Hub honchos. From right, Douglas Kothe of CASL, Nathan Lewis of JCAP, Henry Foley of EEB, George Crabtree of JCESR, and Alexander King of CMI at a recent press event in Washington.

Life after Chu

It's too early to tell whether each hub will reach its technological goal. And the standard will vary. For example, for JCAP to claim success, researchers must simply come up with a practical prototype. And some say that's a long shot. "It will only work if the science is there, and it's not there yet," says Richard Eisenberg, a chemist at the University of Rochester in New York.

In contrast, CASL's success will depend on whether NRC approves its simulations for use in licensing applications. CASL's work so far is impressive, says Jennifer Uhle, deputy director for reactor safety programs in NRC's Office of Nuclear Reactor Regulation. However, approval requires "validating" the simulations' accuracy with reactor data, she says. Given the level of detail in the simulations, data for such validation may be hard to get right away, Uhle cautions. "You can't measure the flow [of water in a reactor] at a billion points without disrupting the flow you're trying to measure," she says.

In spite of the uncertainties, the hubs appear to enjoy support in both houses of Congress. Compared with DOE's traditional research program, the hubs' problem-oriented approach makes it easier for legislators to see what they're getting for their money, says the Democratic Senate staffer. Still, the staffer cautions, to prove their worth the hubs have to produce results that couldn't be achieved otherwise.

The view from the Republican-controlled House is more circumspect. Anxious to protect DOE's basic research programs, some Republican legislators worry that the hubs may duplicate research within DOE and elsewhere. For example, the Republican House staffer says, the federal government already funds 39 initiatives on battery research, including 11 within DOE.

At the same time, House Republicans seem willing to give the hubs a chance. "If you're going to start these things, you should at least finish the first 5 years and look at the metrics and see how these things have succeeded," the staffer says.

Ironically, the biggest threat to the hubs could come from within DOE. The hubs are supposed to break with DOE's traditional way of structuring research. To allow researchers to react quickly to promising leads, the hubs are supposed to be managed with a "light federal touch," says Alexander Larzelere, DOE's program manager for CASL in Washington, D.C. To maintain that autonomy, Larzelere is DOE's only point of contact for CASL, and he says he must make a concerted effort to fend off other bureaucrats. "I spend most of my day trying to keep people from mucking with the hub," he says.

However, that streamlined arrangement means CASL answers to only DOE's Office of Nuclear Energy. So it runs counter to the idea that the hubs should span the stovepipes, says Stanford's Madia. In fact, people have begun to talk about the hubs as belonging to one or another office, he says, so that the batteries hub is an Office of Science hub and the materials hub is an EERE hub.

Such a mindset, Madia says, threatens to obscure a hub's mission to span the spectrum of research, development, demonstration, and deployment of a technology. "If it's going to work, you need a healthy amount of each of these four pieces," he says. "If you get it out of balance, you're just replicating what DOE is already doing."

In fact, some researchers argue that the independence of the hubs is undermined by DOE's failure to follow through on all aspects of the concept. The hubs were supposed to answer to a hubs board, and a hub "champion" within DOE would stick up for them personally, says Paul Hallacher, a political scientist and director of EEB. But those things never materialized, Hallacher says. "There is no DOE hubs program," he says. "There are merely five hubs lodged within different offices." But others argue that such a board would only add another level of bureaucracy to the system.

With no concrete mechanism to guarantee that the hubs maintain just the right amount of autonomy, the fate of the hubs may well depend on how strongly they are embraced by Chu's successor. On 4 March, the Obama administration nominated Ernest Moniz, a nuclear physicist from the Massachusetts Institute of Technology in Cambridge who served as undersecretary in DOE from 1997 to 2001, to be the next energy secretary.

Hubs' proponents are optimistic that Moniz, who was unanimously confirmed last week by the U.S. Senate, will see the value of their work. He's certainly familiar with the concept, having chaired CASL's board of directors from the hub's inception until last year. Still, observers say, Moniz will have lots of other issues to attend to and may have initiatives of his own for which he'd rather push now that he is in office.

Even if Moniz does embrace the hubs' concept, his first task may be to define exactly what a hub is.

–ADRIAN CHO

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