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THE POWER PLAYER

As a physicist, he found a way to capture atoms and won a Nobel prize. Now he is marshalling scientists and engineers to transform the world's biggest energy economy. **Eric Hand** profiles the US energy secretary, *Nature*'s Newsmaker of the Year.

STEVEN CHU is heading home on a bright day in October. His motorcade of government cars powers up the slope of Cyclotron Road, past the fragrant stands of eucalyptus and through the guard station at the entrance of Lawrence Berkeley National Laboratory. The vehicles continue along Chu Road and come to a stop near the top of the hill.

The man after whom the road is named heads into Building 50, which housed his office for the five years that he ran this laboratory overlooking the University of California, Berkeley. Inside an auditorium, 225 former colleagues await his arrival. Some wear suits; others slouch in hooded sweatshirts and sandals. There is an eager anticipation in the air, and moments before Chu arrives, the crowd grows quiet. Orange-vested security guards, armed with walkie-talkies, open the doors, and Chu walks down to the podium, his entourage trailing.

"It's very good to be back here," he says, flipping open his computer. "You people know I do my own PowerPoints. That has not changed." He launches headlong into a fast-paced and scattered talk that leaps across dozens of topics, all under the banner of climate change. He clicks ahead to the crucial slide — the one that shows actual measurements of rising global temperatures outpacing what would be expected without all the carbon dioxide that humans have spewed into the atmosphere. "Here's the evidence," he says. "I have to play this over and over again."

Such is his task back in Washington DC, where Chu now works as Secretary of the Department of Energy (DOE) and a member of President Barack Obama's cabinet — the first Nobel-prizewinning scientist to hold such a high office in the US government.

He is charged with transforming the world's biggest energy economy, and he has assumed the role of persuader-in-chief, trotting before Congress to explain the science of climate change and his plans for combating it. Meeting regularly with representatives and senators, he targets sceptics and walks them through the data. "I say, 'Come to my office and we'll talk about it'," he explains. "At the very least you can put a little doubt in their minds. If they're so sure it's natural causes, they may be less sure." It helps to have a Nobel prize, he adds.

In confronting what he sees as the most pressing problem facing the world today, Chu looks back in time to chart a way forwards. The Berkeley lab he once ran is the descendant of the Radiation Laboratory, where the physicist Ernest Lawrence helped find ways to enrich uranium for the Manhattan Project. Chemist Glenn Seaborg's team discovered plutonium there, and theoretical physicist Robert Oppenheimer worked just down the hill before heading into the New Mexico mountains to build the first nuclear bombs.

> "Necessity is the mother of invention and this is the mother of all necessities."
> — Steven Chu

Chu plans to tackle climate change by reviving the scientific and technological urgency of the Manhattan Project — enlisting some of the nation's best minds to find a way to power the world without ruining it. His plans start at home, where he is trying to push the ponderous DOE to support riskier research that could yield huge dividends.

With a budget of US$27 billion, the department runs 17 national laboratories, oversees America's nuclear stockpile and manages the environmental clean-up after the early nuclear age. It is the largest source of funds for physical-science research in the United States, and this year Chu had a much bigger pot to dole out. Just one month into his tenure, Congress gave the agency $37 billion in economic stimulus money — funds that Chu is steering towards renewable energy, nuclear power, carbon-sequestration pilot plants and projects to modernize the electric grid, all of which should help to solve the climate problem. "They say that necessity is the mother of invention and this is the mother of all necessities," he says. "So we're going to get the mother of all inventions. And it's not going to be just one, it has to be many."

Hands-on manager

In the 1980s, Chu made his name scientifically by trapping atoms using lasers tuned with the utmost precision. Now he is applying that same mastery of detail to a vastly more complex system: an agency of 100,000 people working on all aspects of energy and nuclear issues.

Some Washington veterans have questioned whether Chu's research talent and hands-on style of management will serve him well, both at the DOE and amid the harsh political environment of the nation's capital. He has made some mistakes, notably in his dealings with Congress. But nearly a year into his tenure, Chu has proved that he is a quick learner. He has established himself as a voice that can be trusted by politicians of various stripes. He has helped to bridge international divides, particularly between the United States and China. And he has lured some top scientists from industry and universities to join him at the DOE in his quest.

Carol Browner, Obama's climate tsar, works often with Chu as part of the president's 'green cabinet', a group of senior officials who oversee environmental matters. "I think he's going to turn out to be the best energy secretary ever," she says. Praise also flows from some Republican politicians. Samuel Bodman, who led the DOE for former president George W. Bush, says that Chu has "shown skills as a manager. I think it was an inspired choice by the president to pick him."

Growing up in a New York suburb during the 1950s, Chu and his two brothers learned quickly that academic

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excellence — and competition — were family traditions. The boys would watch *College Bowl*, a 1960s television quiz show, and "the three of us would shout out answers and try to beat the contestants", recalls Morgan Chu, the youngest brother and a high-profile lawyer in California.

Chu's father and mother fled China during the Second World War and both did graduate work at the Massachusetts Institute of Technology (MIT) in Cambridge. The eldest son, Gilbert, followed the path of academic prestige — accumulating science degrees from Princeton University in New Jersey and MIT before gaining an MD from Harvard University in Cambridge, Massachusetts. Morgan did a PhD in social science before heading to Harvard Law School. Steven, on the other hand, was the A-minus student who favoured tinkering over schoolwork. In a family of Ivy Leaguers, he says he was the "academic black sheep", who settled for the University of Rochester in New York, where he studied mathematics and physics. Family pressures, he says, drove him — and frustrated him — early on, but once at Rochester, his facility for science flourished. "All of a sudden, the things they wanted me to do were very natural," he says.

On entering graduate school at Berkeley in 1970, Chu began a love affair with lasers. The work that was once a chore became the focus of an obsessive energy. "I've never been that good at apportioning time," he says. "When I got really excited about something, I would dig into it. It turns out that is a quality that the best researchers have." Another Berkeley graduate student, Phil Bucksbaum, recalled nearly getting into a fist fight with Chu because he was being "bossy about the lasers", until a third student, who had studied with Chu at Rochester, explained to Bucksbaum: "It's the way he always has been. Focused and brusque," says Bucksbaum.

Chu's graduate work using polarized light to probe atomic transitions was good enough for him to get a job at Bell Labs in New Jersey, then a utopia for basic research. Chu thrived there, but he also made sacrifices. As his work progressed, he spent more time away from home, says his ex-wife, Lisa Chu-Thielbar. Sometimes, she would smuggle his first son, Geoffrey, under her overcoat onto the laboratory campus to catch some time with his father. "He was always a scientist first and a father second," says Chu's second son, Michael, who doesn't fault his father for the singular focus that allowed him to achieve so much. "The ambition was all intellectual and scientific. Steve never cared about money. He didn't even care about advancement," says Chu-Thielbar.

After seven years at Bell Labs, Chu had a key insight in 1985 into how to trap atoms. He crossed six lasers to form what he called "optical molasses", a goo of photons. It slowed atoms nearly to a standstill, making them sluggish enough to be held by the electromagnetic forces of an additional laser.

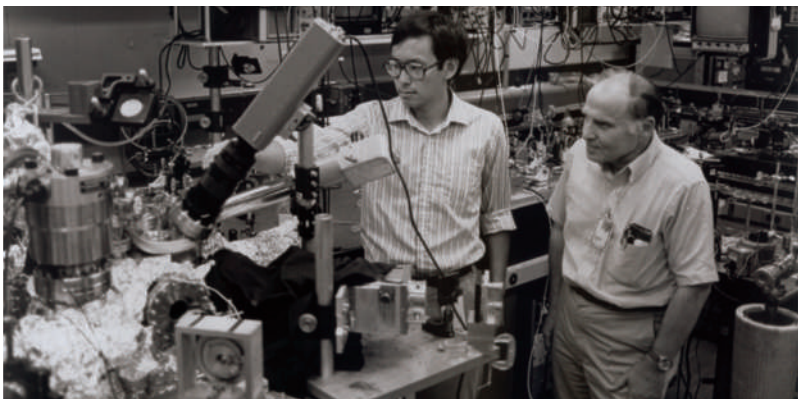
A year later, in the winter of 1986, Chu glimpsed the foundation of his Nobel prize through the windows of a vacuum chamber. Sodium atoms, cooled in optical molasses to 240 millionths of a degree above absolute zero, grew

bright orange as they fell, one by one, into a trap the size of a sand grain. A colour photo, the first ever published in *Physical Review Letters,* provided the proof of his success (S. Chu, J. E. Bjorkholm, A. Ashkin and A. Cable *Phys. Rev. Lett.* **57**, 314–317; 1986). The work would spawn applications across several disciplines. It provided biologists with 'optical tweezers' — ways to manipulate individual biomolecules, such as DNA. And it gave other atomic scientists the tools to create Bose–Einstein condensates, the super-cooled states of matter that can trap light and bring photons to a standstill, in a reversal of Chu's original technique.

By 1987, Chu was ready to move back to academia. He had offers at Harvard and Berkeley, but was intrigued at the idea of helping to build up a less-celebrated physics department at Stanford University in Palo Alto, California. It was a good plan. Stanford soon became a powerhouse; beginning in 1995, physicists there would win four Nobel prizes in a row, including Chu in 1997. While at Stanford, Chu started to push off in new directions, personally and professionally. He divorced Chu-Thielbar and married Jean Fetter, a physicist and former dean of admissions at Stanford. He took on graduate students with interests in biology and helped to convince the Stanford administration to build a $150-million biophysics centre.

But in 2004, just after that centre was completed, the Lawrence Berkeley National Laboratory (LBNL) came calling. Chu, who had never managed anything bigger than a physics department, was ready to make the leap to running the laboratory, which now has 4,000 employees and a $650-million budget. He showed his mettle early on, pushing the University of California system, which manages the LBNL, to use its debt service in an unprecedented way to finance new buildings for the lab, and fighting to save employee pension plans. Chu personally argued on behalf of his employees with the president of the University of California system until he relented, says Graham Fleming, a chemist at Berkeley and Chu's deputy at the time. "If one argument didn't work, he'd try another," he adds.

"Steve never cared about money. He didn't even care about advancement." — Lisa Chu-Thielbar



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DOE

Clockwise from top left: the Nobel call, biking to work this year and time at Bell Labs.

The climate crusader

Chu says that there was no one moment when he decided to devote himself full time to climate and energy puzzles. He had been digesting the science for years, reading reports of the Intergovernmental Panel on Climate Change. And he had pursued energy efficiency in his own life with his customary precision, complaining when workers skimped on insulation in his Stanford home. But soon after arriving at the LBNL, he decided that the time was ripe to resurrect an energy-research programme that had lain largely dormant since the fuel crisis of the 1970s. The lab was ready to revive those efforts, but it needed Chu's energy and vision, says Paul Alivisatos, who succeeded Chu as the head of the LBNL. "It's a bit like a supersaturated solution that you drop a seed crystal into," he says. "Steve was the seed crystal."

Chu gave the sprawling lab a purpose and convinced many scientists to make the switch, as he had, into energy research. He attracted large infusions of funding from the DOE and from the energy company BP. The lab launched major initiatives in biofuels and photovoltaics, but Chu also got involved in the little stuff. Alivisatos recalls Chu's interest in revamping a system of old, lumbering shuttle buses that circle the heights of the Berkeley Hills. Chu would stand on the balcony of the director's office and keep tallies of riders at a bus stop. "He thinks at an incredibly high level, but he also delves down into the finest detail," says Alivisatos. "And one of his abilities is to find the salient detail that matters enormously to the big picture and to show you how those connect."

But some thought that Chu went too far by micromanaging lab operations. "He doesn't see the necessity to get other people involved," says one scientist who knows him well but did not want to be identified as criticizing an official who controls so much research funding. "His whole career has been founded on his fantastic ability to worry about all the details himself. And that makes it hard for him to empower an effective staff."

Obama's election, and his campaign pledges to revamp the US energy system, created new opportunities for Chu. A few weeks after the election, Chu flew to Chicago to meet with the president-elect. "A lot of people are telling me you're the person for the DOE," said Obama, according to Chu. Rarely at a loss for words, Chu could only think to quip, "Who are these former friends of mine?"

Inspired by a sense of service, Chu planned to accept the job, but he did have a demand. He had seen the energy department hamstrung in the past by ineffectual people placed in posts to satisfy political obligations, so he

wanted control over senior appointments. "There was a reasonable shot I could attract the right people. There are a whole bunch of people that have to lift this load," Chu says. Obama agreed, and Chu has recruited top talent such as Steven Koonin, former chief scientist of BP and provost of the California Institute of Technology in Pasadena, who is now undersecretary for science.

On the top floor of the energy department, portraits of secretaries past preside over the long, carpeted hallway leading from the elevators to the secretary's office. Most are of career politicians, with a few exceptions: Charles Duncan, who ran his family's coffee company, Donald Hodel, who would go on to lead two Christian evangelical groups, and James Edwards, a dentist. Bodman, Chu's predecessor, has an engineering degree from MIT. But Chu is the first scientist to lead an agency that has such an important role in physical-science research.

On an end table in his waiting room lie some recent biophysics papers on which Chu is a co-author. Chu puts the papers out to make a point — to visitors and himself — that he is still a working scientist. During his time at the LBNL, he kept a small research group of Stanford and Berkeley students, holding group meetings on Friday nights and on weekends. Even now, he says, he finds a little time for research during plane flights. Although Chu's October visit to the LBNL was his first lab-wide talk, he had visited before to check in with postdocs and meet new, young scientists — trips that Alivisatos calls Chu's "science vacations".

During an interview at his office, Chu settles into the centre of a couch, his back to an expansive view of Washington DC's mall and the Smithsonian Castle. At 61, Chu is resolutely trim. Although he no longer commutes to work by bike, as he often did at Berkeley, he manages long weekend rides and regularly climbs the seven flights of stairs to his office. Chu leans back when he listens, which is often, and leans forward when making a point. He is quick to crack a joke and eager to please. At least, he's that way with politicians (and reporters). With scientists, he can be impatient. "He does not suffer fools," says Michael Levi, an astrophysicist at the LBNL.

O. MUHAMMAD/THE NEW YORK TIMES/REDUX/EYEVINE

Chu was sworn in the day after President Obama.

Chu retains a scientist's candour — and that can sometimes get him into trouble. At his confirmation hearing, some senators jumped on Chu for calling coal "his worst nightmare" in a 2007 talk. (Chu says that the United States, China and India are unlikely to turn their backs on their huge coal reserves and that underscores the need to find clean ways to use the fuel.) A month after taking office, Chu slipped when he told reporters that it was "not in his domain" whether the Organization of the Petroleum Exporting Countries (OPEC) should cut oil production, an impolitic statement. He acknowledges that he was surprised at how his words have been magnified by the press.

Yet his inability to mince words is also an asset, especially in the floors below him in the DOE's headquarters, a fortress on concrete stilts. The DOE national labs have been characterized as inefficient, but that is in part because past safety and security lapses have led to a culture that stresses caution over aggressive research. When, during his talk at the LBNL, Chu mentions his desire to return to the original spirit of the labs, GOCO — government owned, but contractor operated — he gets a hearty round of applause. Chu says that the risk-averse culture, at both headquarters and the labs, must be changed. "The best way to protect yourself from something bad happening is to not do much."

Chu has already made headway. When he found out that billions of dollars in loans for energy projects that had been authorized in 2005 had not progressed, he insisted that they be pushed out in months, with the first one going to a solar-power company. It has helped to get involved personally, he says. Before closing on a $5.9-billion loan with Ford Motors, Chu says he was talking to the firm's chief executive every third day — an example that sent a clear message to his subordinates to act. "In certain areas, I'm not going away," he says. "The pressure is not going to let up."

To encourage more adventurous research, he has pushed to develop the Advanced Research Projects Agency-Energy, known as ARPA-E, which draws its inspiration from DARPA, the celebrated research programme run by

Blue sky, green tech

Under the leadership of Steven Chu, the US Department of Energy has started to fund high-risk energy projects through its Advanced Research Projects Agency-Energy. In October, 37 projects won a total of $151 million, including the following examples.

Carbon capture with artificial enzymes
Significant energy is needed to capture and store carbon dioxide from the combustion of fossil fuels. But a low-energy solution exists — in the human body. CO_2 from cells dissolves in the bloodstream then comes out of solution in the lungs. The enzyme involved, carbonic anhydrase, works at body temperature in both reaction directions. A US$2.3-million grant went to United Technologies Research Center in East Hartford, Connecticut, to explore the enzyme as a model for developing an artificial carbon-capture enzyme.

Giant liquid-metal batteries
One idea for improving batteries draws its inspiration from aluminium-smelting plants, which use huge, sustained, liquid reactions that suck up currents of half a million amps. A team from the Massachusetts Institute of Technology in Cambridge won a $6.9-million grant to try to reverse this process to create a giant battery. The idea could reduce energy-storage costs by an order of magnitude and scale up batteries to the size of buildings. These could store wind or solar energy during the day and release it at night.

LAWRENCE BERKELEY NATL LAB

Berkeley giants such as Ernest Lawrence (left), Glenn Seaborg and Robert Oppenheimer (right) have inspired Chu.

the Department of Defense that had an important role in creating the Internet. ARPA-E is designed to pursue high-risk, high-reward research on new forms of energy and conservation (see 'Blue sky, green tech'). The programme preceded Chu, but it's a pet of his, not least because he recommended it as a co-author on an influential study by the National Academies entitled *Rising Above the Gathering Storm*, which in 2005 warned of declining American competitiveness.

The ARPA-E concept will work, says Chu, only if the smartest reviewers are enlisted to pick out the most innovative ideas — otherwise incremental research is rewarded. "I unfortunately can't review all of the proposals myself," he told a group of clean-energy businesspeople in October, only half-jokingly. So Chu wrote a letter to the presidents of top research universities asking them to nominate their best researchers as ARPA-E reviewers. Five hundred responded to the call for duty.

Chu himself spent about two hours with the final set of proposals. Fleming, Chu's former LBNL deputy, says this sort of task suits his old boss. "I've never known anyone able to go away and come back 10 minutes later knowing so much about a new topic." And on the day that he visited the LBNL, Chu announced the 37 winning proposals, which would use $151 million of an initial $400 million given to the programme.

Chu's most ambitious idea has been to create eight focused and independent energy labs, modelled after the Manhattan Project, to develop technologies such as next-generation batteries and advanced nuclear power (see 'Chu's innovation factories'). But this is where he has run into the most trouble, and it exposes the limitations of the do-it-all-yourself approach. As Congress debated whether to fund Chu's new labs in fiscal year 2010, staffers found that they couldn't get the details on what, exactly, the DOE wanted. Would they be virtual labs, or permanent facilities? How many years would they be funded for? What mix of basic and applied science would be supported? "The hubs were just dropped on Congress," says one congressional staffer who adds that Chu's office did not provide consistent or timely information.

The communication problems with the Hill were on display at a hearing of a congressional appropriations committee in May. Senator Diane Feinstein (Democrat, California), a friend of Chu's, had a complaint. She had wanted to talk privately with him about some solar projects, but she had not been able to make an appointment to see Chu via his staff. "I'm a little bit surprised if you asked to see me and my staff said no," Chu replied.

"We just haven't gotten a response, that's sort of the way it's done," said Feinstein in an apparent attempt to educate the secretary on Washington customs. But Chu, who likes to deal with issues himself, did not seem to understand. "I'm still surprised," he said. "You actually have my private number."

In the end, when Congress doled out money to the DOE, Chu lost some battles. Money that he had proposed cutting from hydrogen research was reinstated. A $115-million education programme he had championed received nothing. Worst of all, for Chu, only three of his eight energy hubs were funded.

Chu's critics say that more attention to Congress could have alleviated the problems, but nearly a year into his tenure, he has not appointed an assistant secretary to head up his legislative-affairs office. Chu says the vacant position was not the problem. The issue was that he hadn't followed through himself. "The failure was on my part," he says, "because I wasn't communicating what the real vision was."

Energy ambassador

On a cold day in early December, Chu was preparing to travel to the United Nations' climate-change conference in Copenhagen. Before the trip, one of the last public events on his schedule was to appear with Secretary of Com-

Chu's innovation factories

Drawing on his experience at Bell Labs and his knowledge of the Manhattan Project, Secretary of Energy Steven Chu has proposed eight 'energy innovation hubs', in which scientists and engineers would work under one roof and be led by a strong director. Each hub would get $25 million a year for 5 years. This year, Congress funded just the first three in the list below.

Topic	Aim
Fuels from sunlight	Invent artificial photosynthetic systems to make liquid fuels directly from atmospheric carbon dioxide.
Energy-efficient building systems design	Create building-control systems analogous to the computerized optimization of car engines.
Modelling and simulation for nuclear reactors	Design fourth-generation nuclear reactors to go far beyond current designs.
Extreme materials for nuclear energy	Develop advanced materials for use in nuclear technologies, including fuels, shielding and waste.
Batteries and energy storage	Research new materials and structures to improve storage density and charging-cycle lifetimes.
Solar electricity	Find new photovoltaic or solar thermal approaches for generating electricity.
Carbon capture and storage	Reduce the cost and energy drain of carbon capture with novel absorbents; find new approaches to chemical, physical and biological separation.
Grid materials, devices and systems	Develop advanced materials for transmitting power; make 'smart' sensors that direct energy more efficiently.

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Busy schedule: Chu likes to take care of many details on his own.

merce, Gary Locke, to talk about speeding up the process for granting patents on green technologies.

In July, the two secretaries went to Beijing together to meet with Chinese energy ministers. Locke, a prominent politician of Chinese descent, was greeted warmly. But Chu, with his Nobel-prize pedigree, was a rock star in a culture that reveres education. "He was like a Michael Jordan," says an administration official. "Everybody knew this guy."

Chu has taken a particular interest in China not because of his ancestry, he says, but because it emits more carbon dioxide than any other nation and it is also spending billions of dollars on clean-energy research. During the trip, Chu and Locke announced that the United States and China would jointly pursue research in areas such as energy efficiency and capturing carbon dioxide from coal-plant exhaust.

In his trip to Denmark, Chu reprised his role as energy ambassador. He announced plans to hold a conference next year with foreign energy ministers and pledged $85 million in US aid for renewable-energy projects in the developing world. For Chu, the summit served as a prelude to the fight next year, when he will use his main weapons — knowledge and powers of persuasion — to try to convince members of Congress to vote for a climate bill that would for the first time cap US emissions of greenhouse gases.

Chu says that when he ends his time as energy secretary, he will measure his success by two criteria: whether he aided adoption of a climate bill, and how much he changed the way that the DOE supports science. Those metrics would have seemed odd to a young scientist at Bell Labs in the 1980s who spent his days fretting over the precision of laser beams. Chu didn't plan on working his way to the upper echelons of the US government, where he is the first scientist since the cold war to play such an active part. "It just sort of happened," he says. "I followed the path first from going and doing the science, to getting very concerned about some issues that affect us all as a society, to finally saying, I can't sit idly by and occasionally give a talk on this. I really have to get proactive and put my money where my mouth is and do a career shift because it is that important."

"One of his abilities is to find the salient detail that matters enormously in the big picture." — Paul Alivisatos

But looking back, it's possible that the call to public service may have been whispering to Chu even during his graduate-school days at Berkeley, where the memories of the war effort remained fresh in the physics department. When Chu briefly took up sculpting at Berkeley, he chose to make a bust of Oppenheimer, the physicist-turned-manager who oversaw all details of the Manhattan Project.

Chu is now looking to another Berkeley star for inspiration. Lately, he has been reading the journals of Seaborg, who led the war-time team racing to extract plutonium for a bomb. Seaborg recounts how his group required fast-working Geiger counters that were not available at the time. So he pushed his crew to invent the needed detectors. For Chu, that sense of urgency in the face of a great threat stands out in Seaborg's work: "He kept saying: 'This isn't university research. We've got to move much faster'." ■

Eric Hand is a reporter for *Nature* based in Washington DC.

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