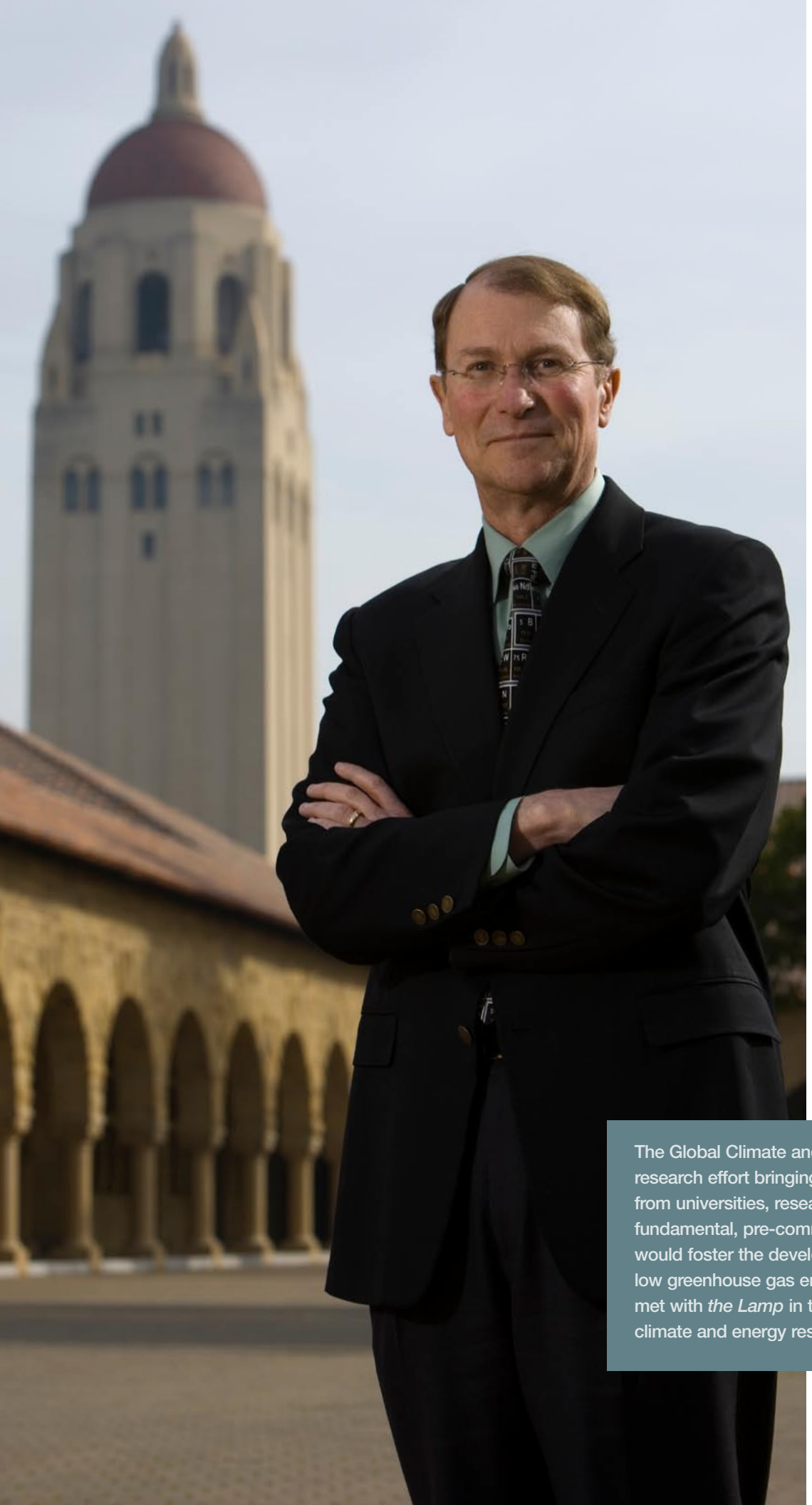

Advancing Climate and

The Global Climate and Energy Project (GCEP) is a long-term research effort bringing together the world's leading scientists from universities, research institutions and private industry in fundamental, pre-commercial research on technologies that would foster the development of a global energy system with low greenhouse gas emissions. Drs. Lynn Orr and Sally Benson met with *the Lamp* in their Stanford University offices to discuss climate and energy research in the 21st Century.

What was the genesis of the Global Climate and Energy Project?

ORR: The project came about through a series of conversations initially with ExxonMobil and Schlumberger. It started as a conversation about geologic storage of CO_2 – also known as CO_2 sequestration. It then evolved into a discussion of a broader effort that might consider more ways to reduce greenhouse gas emissions associated with energy use. ExxonMobil took the lead in making the conversations happen with Toyota and General Electric that brought the full group together. Brian Flannery and Frank Sprow at ExxonMobil played pivotal roles in all those conversations. I was the Dean of the School of Earth Sciences here at Stanford then, and I

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worked closely with colleagues in Earth Sciences, the Dean and the Senior Associate Dean in Engineering as we thought about how the project might work and where it all would lead. So that's how it came together.

Dr. Benson: After a distinguished career in leadership roles at Lawrence Berkeley National Laboratory, why did you decide to join the GCEP team?

BENSON: I think the Global Climate and Energy Project is an incredibly important project. I wouldn't be here if I didn't think it was. It has great potential to make a real difference. I think it's fantastic that ExxonMobil and the other sponsors came together to fund this very large, forward-looking program. GCEP's focus on science and technology is going to lead to real solutions and real options. In the United States, we've been privileged to have abundant, affordable, reliable energy. It's always there for us providing energy for heating our homes to lighting to transportation. So Americans haven't had to question very much about energy. But in my view, on a whole spectrum of issues – from energy security to the carbon dioxide issue – people need to start learning more about energy. I think GCEP can play an important role as a place for people to get solid information and facts about our energy options going into the future.

Why is it important to reduce greenhouse gas emissions?

ORR: The time is coming when we will have to use energy more efficiently and also deal with limits on carbon. You are already seeing that in some places. California has just passed a set of rules that will set some limits on carbon emissions and Europe already has them.

BENSON: One of the reasons GCEP is so exciting to me is because we have a portfolio of excellent fundamental research and new energy systems that help us deal with the CO_2 problem. The idea behind CO_2 capture and storage is that you strip carbon dioxide emissions from power plants or other stationary sources, you compress and transport it and then you inject it into a deep underground formation. GCEP is focused on solutions, on finding a portfolio or a suite of technologies that would ultimately be able to reduce emissions across all of the sectors with large CO_2 emissions.

What factors do you consider when evaluating new additions to your research portfolio?

ORR: We look for a combination of good science and potential for impact on greenhouse gas emissions and also for projects that might lead to some new options for reducing greenhouse gas emissions. We use an external peer review system to evaluate proposals, so there's a lot of rigor in the proposal evaluation process. What we have now is quite a wide-ranging portfolio of research. Lots of solar, lots of biological conversions, lots of fundamental chemistry and electrochemistry applied to energy conversions in systems that range from fuel cells to advanced engines, along with research on novel systems for carbon capture and storage. We're serious about thinking broadly across the ways we might work to reduce greenhouse gas emissions. And central to that effort is the idea of building the underlying fundamental science and engineering science that it will take to support the development of those kinds of technologies.

Dr. Franklin M. Orr, Jr.
Global Climate and Energy Project (GCEP) Director
Stanford University

Franklin M. ("Lynn") Orr, Jr. became the Global Climate and Energy Project director in November 2002. He is the Keleen and Carlton Beal Professor of Petroleum Engineering. From 1994 to 2002, Orr was the Chester Naramore Dean of the School of Earth Sciences at Stanford University.

Orr earned a bachelor's degree in chemical engineering from Stanford in 1969 and his doctorate in chemical engineering from the University of Minnesota in 1976. He joined the Stanford faculty in 1985.

Orr's research interests include multiphase flow in porous media; interactions of high-pressure phase equilibria of multicomponent mixtures with multiphase flow, with applications to enhanced oil recovery by gas injection processes and contaminant transport in aquifers; modeling of large-scale, hydrodynamically unstable flows in naturally heterogeneous porous media; theory of first-order partial differential equations as applied to chromatographic separations that occur during multiphase flow in porous media; capillary phenomena of near-critical fluids in porous systems; and gas hydrates and CO_2 sequestration.

Orr was elected to the National Academy of Engineering in 2000. He is a member of the boards of directors of the Monterey Bay Aquarium Research Institute and the David and Lucile Packard Foundation.

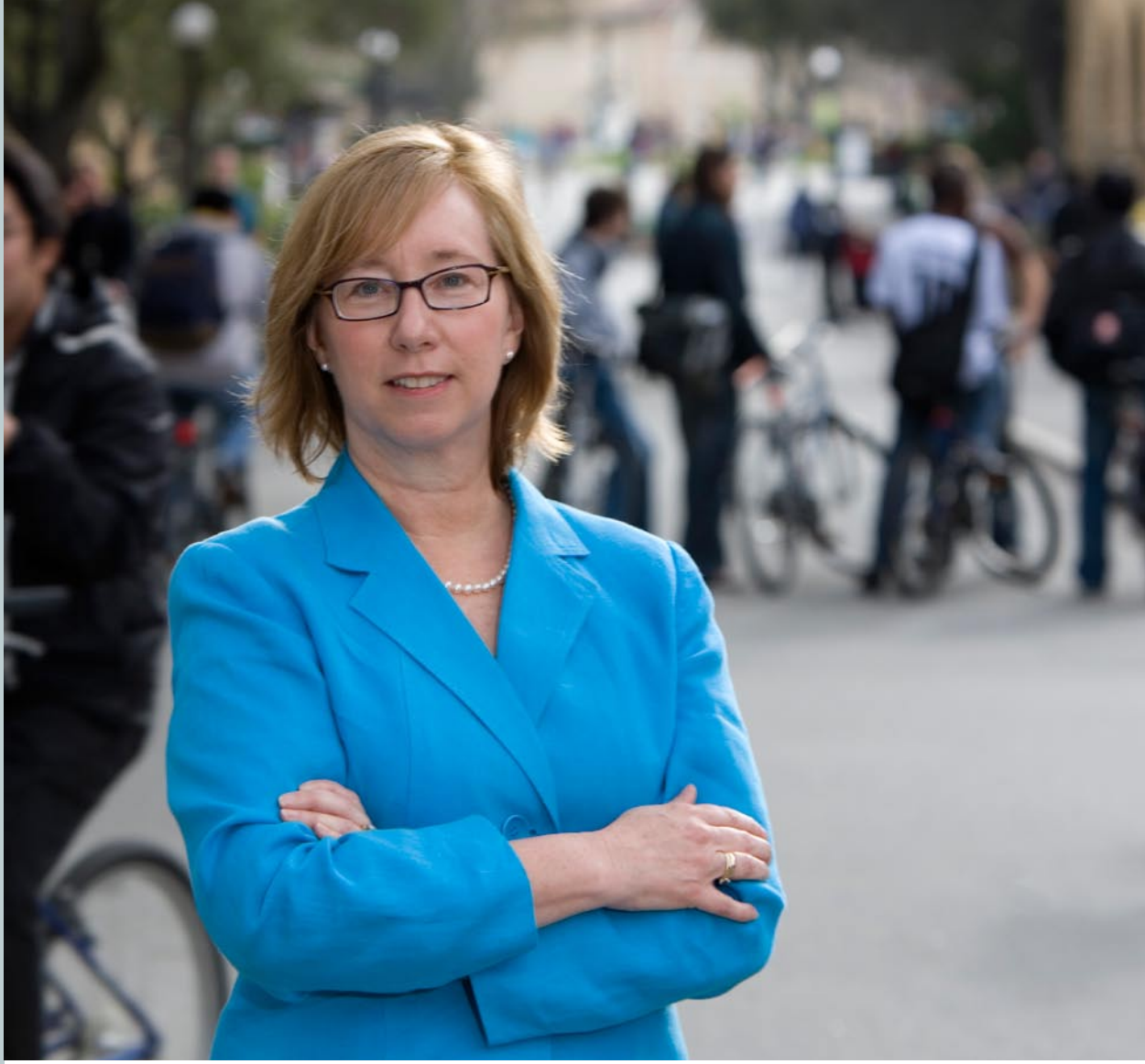
Dr. Sally Benson
Global Climate and Energy Project (GCEP) Executive Director
Stanford University

Sally Benson, a staff scientist and former deputy director for operations at Lawrence Berkeley National Laboratory (LBNL), became executive director of the Global Climate and Energy Project (GCEP) at Stanford University on March 1, 2007.

As executive director, Benson reports directly to Dr. Lynn Orr and will guide the development of the diverse research portfolio for GCEP. In addition, she will hold a research faculty appointment in the Department of Energy Resources Engineering in the School of Earth Sciences, where she will lead efforts to study mechanisms by which carbon dioxide can be trapped in underground formations. A groundwater hydrologist and reservoir engineer, Benson has conducted research in a range of areas including geothermal energy and groundwater cleanup. Prior to completing a four-year term as deputy director at LBNL in 2004, Benson served as associate laboratory director for energy sciences and as director of the Earth Sciences Division, both at LBNL.

Benson graduated from Barnard College at Columbia University in 1977 with a bachelor's degree in geology. She completed her graduate education in 1988 at the University of California, Berkeley, and received her M.S. and Ph.D. degrees in materials science and mineral engineering.

A member of a number of organizations including the American Geophysical Union and the Society of Petroleum Engineers, Benson has served on various committees including the Stanford University Earth Sciences Advisory Board. She is author or co-author of more than 160 scientific publications.



How are you sharing the ideas and technologies being developed by GCEP?

ORR: We're trying to make sure the pipeline is as full of ideas as we can make it, so that over time there will plenty of ideas that can be tested in the marketplace to see what goes forward. Obviously, we publish and speak about the science and engineering science, and we talk regularly with our research colleagues around the world. GCEP is completely open. Everything we do is public information, and if it's good enough, it is published. That's a fundamental principle for Stanford University, and it is completely supported by the sponsors as well. A few weeks ago, we had a delegation visit from Britain. They were asking about interdisciplinary research and innovation and about how we go about working on what we're doing. Another group from Tokyo Institute of Technology came asking similar kinds of questions because they are setting up a research institute at their university that might have similar aims. So, there's plenty of conversation with colleagues all around the world.

BENSON: I expect to get out and speak to people about GCEP. I especially like to talk to people in plain English to try to demystify a lot of science. Once people understand things better, it's much easier for them to evaluate what the issues are and what solutions and options are available or will be in the future.

What is your approach to examining ways to improve energy efficiency?

ORR: There's a big potential in the United States to be much more efficient in the way we use energy. That is an area where ExxonMobil has taken the lead in its own operations. We're working on areas that have a strong connection to efficiency.

For example, we are looking at a variety of advanced fuel-cell concepts that would allow much more efficient conversion of energy into electricity and also might allow using hydrocarbons in fuel cells. We are also looking at the potential for much higher efficiency internal combustion engines.

Why is developing new technologies so important to future energy consumption?

ORR: About 2 billion people on the planet don't have ready access to energy resources. As they develop greater economic capacity to use them, demand will grow. Meeting the growing demand for energy by relying on current technologies will lead to much larger carbon emissions. So, our job is to provide as many options for that set of transformations as possible.

What are the technical barriers to the large-scale application of the technologies you are working to develop?

ORR: The biggest barrier is cost. For example, the really big resource in terms of daily energy flows is the sun. But we don't rely on the sun for electricity because the cost of photovoltaics is substantially higher than the cost of other ways of making electricity. In the end, energy technologies will have to compete in the marketplace. In addition, for each technology, there's a whole host of engineering issues and perhaps environmental issues that have to be thought. That complexity is what makes this project so interesting.

What is the near-term outlook for hydrogen as a solution to future energy demand?

ORR: Hydrogen is not an energy resource, it's an energy carrier. So you might think of hydrogen as something like a battery. You can make hydrogen in a variety of ways, but it must be made from some primary energy resource. You can make it from electrolysis (though this obviously requires the electricity to be made somehow), from methane or by gasifying coal, heavy oil or biomass, for example. Depending on how the hydrogen is made, there may or may not be carbon emissions. The appeal of hydrogen as a carrier in a transportation system is the potential for high-efficiency conversions on the vehicle with a fuel cell and the fact that only water is emitted from the vehicle. The fuel cell takes hydrogen and makes electricity that is then used to drive an electric motor. That appeal is balanced by the fact that the energy conversions required to make hydrogen are not 100 percent efficient, so cost and overall efficiency of all the steps from primary resource to a moving vehicle must be considered. There are also other major issues to be addressed, such as how to distribute the hydrogen to your local hydrogen station, how to store it in sufficient quantity on the vehicle, and safety. So it's definitely not just around the corner – and for cost reasons probably more than any other. The catalysts we use in fuel cells and the cells themselves are still very expensive.

What is the outlook for wind power?

ORR: Wind is close to commercial now, depending on how you do the comparisons, with little or no subsidy. As the bigger wind turbines come on line, you get some economies of scale. So I think you'll see more wind power installed. But because it is growing from such a small base, even with high growth rates there will still a way to go before we see significant penetration.

Are you concerned about the level of scientific literacy in the United States today?

ORR: I think we have a long way to go in that area. We could do much better in terms of having a populace that is well enough educated to be able to listen to all the debates and form a reasoned opinion. The energy areas are good examples of systems that we take for granted but are very complex. That gives us all a responsibility to talk to groups that want to hear about it and to talk to students and teach. One of the things that I have enjoyed most about GCEP is that it has helped engender more teaching at this university.

BENSON: Unfortunately, a lot of people get turned off by science at an early age. We are truly fortunate to live in a society that is underpinned by the most amazing technology. Given our reliance on technology, we need to have a broader awareness of the underlying science that makes things work, why they work, and the issues associated with the use of technology. I think people need to know more, and we need to teach science in such a way that people are fascinated and curious.

What will Dr. Benson bring to the GCEP enterprise?

ORR: Sally is a very accomplished geoscientist by training and she is internationally known in the area of geologic storage of CO_2. But that's not all she brings to GCEP. In fact, we're also delighted that she's joining us because she has a wealth of very high level research management experience. She served as the head of the Earth Sciences Division at Lawrence Berkeley Laboratory and then as its Deputy Director for Operations. And in between those, she was the Associate Laboratory Director for Energy Research there. Put simply, she's a brilliant scientist and a highly respected authority in a variety of disciplines. And she's the kind of person who will have the respect of our faculty and also the respect of the world outside, so I'm delighted to have her as a key member of the GCEP leadership team.

To learn more
exxonmobil.com/gcep

Do you see yourself as a role model for those considering a career in science or technology?

BENSON: I'd like to believe that I would be a role model, and I hope the things I do might have opened some eyes. Getting and keeping women and girls in the sciences is important. We should help them see that there are real career paths and lots of jobs. They need to hear the message that at the end of your long education, you can have a great job. It will pay you well. You will be rewarded intellectually. And you'll have fun. theLamp