POWER STRUGGLE

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For decades, California has bucked the US trend of gobbling ever more electricity. But can the state pull off an even more ambitious goal and slash its greenhouse-gas emissions? **Charles Petit** finds out.

Arnold Schwarzenegger has a mission: he wants to terminate global warming. In June, the California governor called for the state to slash its greenhouse-gas emissions to 80% of 1990 levels in the next 45 years. "The debate is over," he said in a forthright speech in San Francisco. "We know the science. We see the threat. And we know the time for action is now."

This was fighting talk, but if any advanced economy can pull off such drastic cuts in emissions, this high-technology Pacific Rim state and its 36 million residents probably can. Schwarzenegger has help. His muscle for the job is a team of state energy-conservation experts who have been in the business for years. And first among them is his polar opposite: a short, skinny physicist named Arthur Rosenfeld. More than three decades ago, Rosenfeld helped to trigger the state's successful fight to cut energy consumption; today he is one of the five members of California's Energy Commission.

Rosenfeld was Enrico Fermi's last graduate

student and he spent decades as a physics professor at the University of California, Berkeley. He now commutes weekly between his home overlooking San Francisco Bay and Sacramento, the capital, in an energy-saving Prius hybrid sedan that the state provides. The Energy Commission's job isn't easy: to help the most populous US state figure out how it might cut greenhouse-gas emissions and make money doing it.

Under control

In his office, Rosenfeld pulls out a data plot of which he is particularly fond. It shows electricity consumption per capita from 1960 to 2002, with one line for California and one for the United States. In 1960, both lines sit at 4,000 kilowatt-hours per person. They rise at roughly the same pace to about 7,000 kilowatt-hours in the early 1970s. But at the point when the US energy crisis struck that decade, the lines diverge dramatically: California virtually flatlines its energy use per citizen — even though its economy was outpacing the rest of

the nation. The state's electricity use per capita today is the lowest in the nation at 6,800 kilowatt-hours, compared with 12,800 kilowatt-hours for the country overall.

The strategies that helped California achieve those conservation goals may now help it in its greenhouse-gas cuts. State energy experts, including Rosenfeld, don't foresee California adopting many radical new technologies to meet its ambitious goals. Rather, a steady application of proven technologies should do much of the job.

California's \$1.5-trillion gross annual product makes it the world's sixth largest economy, behind France and ahead of Italy. It is the planet's ninth-largest emitter of greenhouse gases. "California is not an insignificant actor, and we are seen as a world leader in protecting the environment," says Eileen Tutt, a senior officer at the California Environmental Protection Agency. "Not to take action sends a very strong signal."

Still, the governor's pledge, made on the United Nations World Environment Day,

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Harnessing the power of renewable energy such as wind (above) and geothermal (below), California aims to cut its greenhouse-gas emissions.

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caused more than a few jaws to drop. Schwarzenegger is a tax-cutting Republican who owns several fuel-slurping Hummers and is deeply suspicious of government regulation. Beset by budget fights and union opposition, he has sagged in popularity with the state's generally Democratic voters since his election two years ago. But his energy policies, building on those of a string of governors of both parties, get him kudos from longtime activists. "The governor is a real-life climate action hero today," Nancy Ryan, a senior economist with the group Environmental Defense, told reporters after his speech.

Specifically, Schwarzenegger vowed that California will cut its greenhouse-gas emissions to below 2000 levels by 2010 and to less than the 1990 level of 373 million tonnes by 2020. But then the governor added the final, ambitious goal to cut emissions by a further 80% by 2050.

Out on a limb

His policy stands in stark contrast to that of the federal administration under President George W. Bush, who has refused to ratify the Kyoto Protocol to reduce greenhouse-gas emissions. The president has said that such action would squeeze the US economy too much. California officials say that they can do it while boosting the economy and creating jobs. The state's strong environmental policies in the past, they point out, occurred while its economy thrived.

Success will require the cooperation of several interlocking agencies. The Energy Commission plays a major role, as do the state's Environmental Protection Agency, Air Resources Board and Public Utilities Commission. Schwarzenegger's proclamation renewed their "absolute licence to go out and make California a model country for greenhouse policies", says Stephen Schneider, a physicist and climate-policy analyst at Stanford University.

State officials have much at stake. California's climate could change utterly if a warmer world redirected storm paths (see *Nature* 430, 818; 2004). Rising temperatures could cause winter rain instead of snow in the Sierra Nevada mountains, triggering floods for which the state's aqueducts and dams are not prepared. Plus, its coast is vulnerable to a rise in sea level.

Other states have also recognized their vulnerability to climate change, and have independently taken climate policy into their own hands. Local legislators, from mayors of cities to state governors, have begun their own versions of Kyoto-like regulations (see B. Fisher and R. Costanza *Nature* 438, 301–302; 2005). In the northeast, nine states have agreed to cap carbon dioxide emissions from more than 600 power plants in the region (see *Nature* 437, 11; 2005). On the west coast, California has joined

with Oregon and Washington in a governors' initiative to encourage energy efficiency and conservation.

But of all the states, California has set itself up as a model of how diligent attention to efficiency can take root and pay off. Its example has caught on: in recent years many other states have adopted California's standards for car pollution rather than the more lax federal standards.

And the state is now attracting international attention. In September, its Public Utilities Commission, Energy Commission and the Pacific Gas and Electric Company signed a pact with China's Jiangsu province to train officials and utility executives in energy-conservation tactics. Earlier this month, Schwarzenegger led a sales delegation to China to tout the state's energy-saving technologies, and another team from the state's Air Resources Board travelled to Belgium to brief European air-quality experts on energy policies.

California's approach to energy conservation has helped it save money. The state sets electricity rates for private utilities, and sometimes provides subsidies to help power companies induce customers to cut their consumption. If they do, the state gives money back to the companies — through rate adjustments and other payments — that makes up for what the firms would have earned had they built additional power plants.

The Energy Commission calculates that the total power bill for residents is about \$16 billion

lower each year than if the state had not launched its conservation campaign. Conservation has also managed to prevent some 18 million tonnes of carbon pollution being emitted from power plants — equivalent to taking 12 million cars off the roads. After allowing for the cost of measures such as changed building practices, appliances and subsidies, the net saving is about \$12 billion.

And deeper energy cuts should pay more, the commission says. The Air Resources Board estimates that planned reductions in greenhouse-gas emissions by 2020, from motor vehicles alone, could save Californians \$256 million annually by 2010 (mostly from smaller fuel bills), and \$4.8 billion annually by 2020.

Cut and dried?

But will the state's longer-term emissions policy succeed? Schneider is unsure how cost-effective the whole plan will be. Earlier stages may pay for themselves, he says, but the final leap to the 80% cut is unlikely to come without costs. "It would take a total revamp of our fuel infrastructure," he notes.

So far, even state planners aren't sure how they will meet the later goals. "We don't have the details, but we'll have a report to the governor's office in January," says Tutt.

Some fresh ideas are already in the works.

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— Nancy Ryan**

One notion, set out by Schwarzenegger's administration, is to place 1 million solar-panel systems on rooftops by 2018. California gets about 11% of its electricity from geothermal, wind, biomass and solar units; for the United States overall, the number is around 2%. California aims to increase its share of renewable sources to 20% by 2010 and to 33% by 2020.

Also helpful will be the vehicle clean-up legislation enacted just before Schwarzenegger's arrival. This requires car manufacturers, starting in 2009, to cut greenhouse-gas emissions from new cars and trucks by 22% by 2013 and 33% by 2017. But the law remains in dispute — perhaps predictably, car companies have sued. They argue that carbon dioxide is not a pollutant, and that regulating it at state level would pre-empt federal control over the fuel-efficiency standards in new cars. In the long run, the governor has chosen hydrogen-fuelled cars as his personal crusade.

Wind power figures large in state plans. California pioneered wide-scale use of it and already has more than 14,000 wind turbines. In a good breeze their combined capacity is 2,100 megawatts — about the same as two nuclear power plants. State energy officials estimate that wind alone, in principle, can generate an additional 30,000 megawatts.

Fuel for thought

The rest of the renewable energy would probably come from beefed-up geothermal, solar and biomass facilities. In recent weeks, the utility company serving San Diego contracted to buy another 205.5 megawatts of wind power, and the Los Angeles utility company ordered 500 megawatts of solar power from a complex being built some 120 kilometres northeast of the city. When construction is completed in 2013, this will be the world's largest solar facility and will more than double US solar-energy generation. One energy source that is not on the agenda, despite not emitting greenhouse gases, is nuclear power, which now provides about 10% of the state's electricity. California law forbids the construction of additional nuclear plants until safe, long-term waste storage has been assured.

If Schwarzenegger's emissions-busting goal seems ambitious, Rosenfeld is happy to put it in perspective. He recalls the early days of conservation work when he co-founded a programme in energy-efficient buildings at the Lawrence Berkeley National Laboratory. The effort spawned what today is an entire Environmental Energy Technologies Division at the lab.

Back then, Rosenfeld's personal project was to make fluorescent lights more efficient. Around the same time, in 1973, state lawmakers formed the California Energy Commission, which was signed into existence by then-Governor Ronald Reagan.

In its early days, the commission took almost as gospel any reports from Rosenfeld's

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Arnold Schwarzenegger refuels a hydrogen-powered car (top). His vision is to see vehicles like this replace the polluting models on the road.

group on how to reduce energy demand. In 1978, the state used the team's recommendations as a guide to impose energy requirements on new buildings. Appliance standards came two years later governing such items as gas furnaces, air conditioning and refrigerators. Today, due largely to such regulations, refrigerators use a third of the electricity and cost about a third as much to buy as in the early 1970s. In contrast to California's efforts, federal standards, such as 'Energy Star' labels for approved appliances, did not arrive until the 1990s.

Energetic response

The total electricity used for air-conditioning new homes in California is now a third of what it was in the 1970s. And two technologies from the Lawrence Berkeley initiative — the revamped light bulb and window coatings that keep heat out in the summer and in during winter — will save the US economy some \$23 billion in utility bills, the National Academy of Sciences has estimated.

Rosenfeld is not done waging war on wasted energy. He is pushing hard for regulations to encourage the use of white roofs, or at least coloured ones, that reflect most near-infrared radiation. Such cool roofs could save \$200 million yearly in air-conditioning costs in Los Angeles alone. He frets over energy "vampires", the trickle of power that modern appliances continue to suck through their plugs even when they are turned off. Such vampires include televisions waiting for a signal from the remote, cable boxes, modems, recharging cell phones, cordless phones, garage-door openers waiting for a signal and stereos. Standby power, which was insignificant two decades ago, now typically accounts for 10% of a home's electricity use. New technology that gives appliances more efficient standby modes, which California will require as it becomes available, could reduce this by 75%.

"Let me show you something," Rosenfeld says as he pulls out an iconic NASA satellite image of the Western Hemisphere at night. The US industrial centres blaze like constellations against the black backdrop of the continent. "You are looking at millions of light bulbs," he says in dismay. To Rosenfeld, the necklaces of light are not signs of advanced civilization but of a wastrel society leaking precious photons into the void.

Then, Rosenfeld leans forward with a conspiratorial air. "In the next 20 years," he declares, "California will disappear." And that is Rosenfeld's dream — that the state will disappear, or at least fade, at night. Rules enacted this year require new lights for streets, parking areas and the like to focus 98% of their illumination on the ground, not into the sky. Once again, Rosenfeld says, the message for California on saving energy is simple: every little bit helps.

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