Thomas Turnbull
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California's Quandary: Systematising Energy Saving at the RAND Corporation

Abstract

At the beginning of the nineteen-seventies, employees of the RAND Corporation, the archetypal U.S. Cold War think tank, turned their expertise in rational decision making toward the problem of reducing energy demand, first in California and then nationwide. In surveying existing demand forecasting methods, primarily carried out by electrical utility companies, RAND researchers argued that utilities' self-serving extrapolative forecasts contributed to growing energy use. RAND's response was to develop an independent forecasting method, one which recast the various aspects of societal energy consumption in general systemic terms, and which allowed interventions to reduce future energy demand to be tested in lines of code. Heavily informed by a recent iteration of cybernetic thought, the model which was developed suggested demand reducing feedback loops could be introduced into energy system, thereby iteratively reducing overall demand with minimal impact on wellbeing and economic growth. In effect, it was suggested that the entire energy system could be reconceived of as a vast conservation mechanism. In revisiting the history of the science which underlies the now common-sense notion of energy saving, this paper is intended to historicise and problematise current attempts to significantly reduce greenhouse gas emissions via the increased efficiency of energy use.

GROOVY RAND

The salmon pink office of the RAND Corporation on 1700 Main Street Santa Monica opened in 1952. Its airy reinforced concrete rooms with an abundance of glass were typically high modernist. Architect Harold Roy Kelley (1893-1989) had designed buildings for Douglas Aircraft Company during World War II.[1] Perhaps his most unique wartime project had been designing a structure that suspended five million square feet of chicken wire across four hundred high poles towering above Douglas's Santa Monica factory complex. On this canvas Hollywood set designers created a burlap sack simulacrum of a sparsely populated suburbia, filled with fake trees and houses. This extravagant camouflage was intended to deter Japanese bombing raids in Pearl Harbor's wake.[2] Douglas was an understandable target, as under this chicken wire landscape a team of scientists were working on behalf of the U.S. Air Force to find an optimal configuration of variables for the deployment of the B-29 'Superfortress' airplane, calculating a vast number of variations in armour cladding, pay-load, and fuel efficiency in order to maximise the efficacy of bombing raids over Japan.[3] Some of the two hundred employees whose tail-finned cars would later fill the RAND parking lot in '52 had worked on this project, not least former test pilot and airplane engineer Frank Collbohm (1907-1990) who suggested institutionalising this systematic approach to military problem-solving. On the basis of his proposal 'Project RAND' was formed in 1946. Formally separated from Douglas's business operations, the aim was to allow researchers to objectively study the economics of

[1] Kubo, M. Constructing the Cold War Environment: the architecture of the RAND Corporation, 1950-2005.
[2] Paranoia about a Japanese bombing raid was justified, submarines were sighted off the Southern California coast in June 1942, and in February that year, thousands of rounds of anti-aircraft rounds were shot into the night sky, aiming at an imagined assailant in the so-called 'Battle of Los Angeles', Stanley, R. To Fool a Glass Eye: Camouflage Versus Photo-reconnaissance in World War II. Airlife Publishing, 1998, 171-178.
[3] Thomas, W. Rational Action, 119: Smith, The Idea Brokers, 115.

warfare in the air, on land, or even space. In 1946 it was suggested an alcohol and liquid oxygen fuelled rocket, loosely based on the German V-2, could launch an Earth-monitoring satellite.[4] The organisation's wider aim was not to develop weapons so much as strategies for optimising how spending on military research and development was allocated, as with the B-29. Objectivity was key to this, and in 1948, seeking critical distance, it was decided that Project RAND should split with Douglas, becoming an independent non-profit research organisation.[5]

Five years later, local dignitaries and interested neighbours were invited into the new RAND building. There was little to see aside from the usual paraphernalia of office life, other than the machine room at the back of the building in which a large analogue computer *and* an IBM 7044 digital computer had been installed. Guests were invited to play tic-tac-toe or print their name on a punch-card.[6] Such advanced means of calculation were part of a wider repertoire of tools, from slide rules to interview techniques, that RAND used to present itself as the archetypal cold war 'think-tank', a research organisation committed to offering means for rational decision-making.[7] Such organisations had clustered in Southern California, feeding off billions of dollars of Federal investment in the region infrastructure during the Second New Deal.[8] Airplane manufacturers had been attracted partly thanks to such subsidisation, but also due to the state's warm climate and cheap land for building factories and low-density worker housing.[9] Another reason was the nearby California

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[4] Preliminary Design of an experimental World-Circling Spaceship, 1946, presaged Sputnik by 11 years. Edwards, Closed World, 60.
[5] Thomas, Rational Action, 146-8.
[6] Ware, W. RAND and the Information Evolution: A History in Essays and Vignettes, 77.
[7] On the origins of the term think-tank see Rich, *Think Tanks, Public Policy and the Politics of Expertise*, Cambridge, xiii-xiv.
[8] Smith, Idea Brokers, 116; Davis, City of Quartz, 387,
[9] Markusen, The Gunbelt, 1991, 101; Lotchin, Fortress California

Institute of Technology. the academic nucleus of these hi-tech industries. Led since the 1920s by physicist Robert Milikan (1868-1953), the wind tunnel at 'Cal-Tech' had contributed to the development of Douglas's commercial aircraft in the 1930s, and its student body helped Southern California to play host to arguably the highest concentration of PhD holders of any place on Earth.[10]

But RAND's geography was more complicated. The office had also been built just a stone's throw from the attractions of Venice beach in the hope of attracting bright graduates who might otherwise have headed to the East Coast. Its layout had been designed to encourage spontaneous encounters between employees, and lunch breaks could be spent playing *Kriegspiel*, a modified form of oversized chess, in the building's courtyard.[11] When visiting the organisation in 2017, to consult their archives, surfboards propped up in the changing rooms contrasted with the organisation's 'Strangelovian' reputation.[12] Stanley Kubrick's 1964 film had famously satirised the 'Bland' organisation's often absurd strategizing over the question of how to strategically contain or even annihilate the Soviet Union. An early project was the 'Strategic Bombing Systems Analysis', which sought a configuration of B-52 bombers as they carried out a nuclear led response to a Soviet offensive, which would likely have destroyed much of Western Europe.[13] Such thinking was no more baroque than in the work of the exuberant physicist Herman Kahn, whom Kubrick had allegedly based his film's fictional protagonist on.[14] Like Strangelove, Kahn's book *On Thermonuclear War* (1960), based on his RAND work, detailed how to wage nuclear

[10] Davis, City of Quartz, 55.
[11] Kubo, Constructing the Cold War Environment: The Strategic Architecture of RAND; and Kaplan, .51.
[12] in 2017 Erickson et al 2013, Kubo
[13] Thomas, Rational Action, 205.
[14] Ghamari, Worlds of Herman Kahn, 41.

war by building an automated weapon of such catastrophic potential, a 'Doomsday Machine', that pre-emptive aggression would become entirely irrational.[15] RAND's infamy, as one biographer claims, stemmed from such attempts to 'impose a rational order on something that many thought inherently irrational – nuclear war'.[16]

RAND in some ways pioneered the 'Californian ideology', that strange fusion of cultural bohemianism and faith in high technology which later would, emerging from Silicon Valley, seemingly conquer the world.[17] Before then, in the nineteen-seventies, an amalgam of individual autonomy and techno-imperialism found expression in RAND's growing involvement in the war in South East Asia, which would inadvertently transform the organisation.[18] It would be no longer known just for its slide-rule using 'eggheads' and backroom simulations of mutually assured destruction so much as the deeds of Daniel Ellsberg. A former marine and Hawkish opponent of the Soviet Union, Harvard educated Ellsberg had joined RAND in 1957, the year Sputnik's orbit was seen as a portent of Communism's ascendancy. Having worked on nuclear deterrence and given feedback to Kahn, Ellsberg found himself working for U.S. Secretary of Defence, Robert McNamara, whose Office of Systems Analysis, from 1961 onward, had used RAND staff and decision-making methods to more efficiently wage war against North Vietnam.[19] McNamara's vision was that the battlefield could be cast as a closed informational system, in which simulations and forecasts would aim to automate the neutralisation of energy combatants.[20] Beside

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[15] Ghamari, Worlds of Herman Kahn, 17-18.
[16] Kaplan, 10.
[17] Barbrook and Cameron, The Californian Ideology,
[18] Mai Elliot, RAND in Southeast Asia: A history of the Vietnam War Era.
[19] Wells, Wild Man, 146-147; Mai Elliot, 14ll.
[20] Edwards, Closed World, 113-147; McNamara had been a USAF pilot and taken part in bombing raids over Europe and Japan in WWII, as well as strategizing how best to achive their optimisation. Watson, G., Wolk, H."Whiz Kid" Robert S. McNamara's Word War II Service", Air Power History, 50 4 (2003) 4-15.

this work, RAND was tasked with maintaining an objective record of the conflict, and here Ellsberg learnt of the 'morale and motivation' studies which detailed the scale of U.S. atrocities against the North Vietnamese and undermined the supposed heroism of the war.[21] Increasingly drawn to the anti-war movement, Ellsberg handed over seven-thousand photocopied pages of classified RAND research to the *New York Times,* causing public outcry and galvanising pro and anti-war sentiments. Already in the late '60s RAND's chairman Gustave Shubert estimated a third of staff were opposed to the war.[22] These internal divisions became apparent when a management meeting regarding their Vietnam war work, ironically, ended in a fistfight.[23]

The Pentagon Papers also revealed the changing extra-curricular interests of defence intellectuals. Two years later, as details of the Watergate scandal came to light, an inquiry learnt President Richard Nixon's henchmen not only spied on Democratic rivals, they had also sought to 'neutralise' Ellsberg by breaking in to his psychiatrist's office and looking for evidence of his drug use.[24] In step with the times, Ellsberg had indeed experimented with LSD, at one point with the assent of his employer. The substance had been administered by RAND psychologist William McGloughlin as part of an after-work psychotherapeutic experiment in documenting attitudinal change in 'normals'. Kahn reputedly also indulged.[25] Far from the staid rationalism of the 1950s, by the 1970s RAND had become a place where employees voiced anti-war sentiments and experimented with psychedelics. They even took part in

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[21] Herken, Councils of War, 223.

[22] Jardini, Thinking Through the Cold War: RAND, National Security and Domestic Policy, 1945-1975, Smashwords, 2013. ft 761. unpaginated

[23] Jarindi ft 763

[24] Tom Wells, Wild Man: The Life and Times of Daniel Ellsberg (2001) Palgrave. 169-170

[25] The experiments took place at the LA Veterans Administration Hospital, William McGlothlin, 'Long-lasting effects of LSD on certain attitudes in normals: an experimental proposal', 1962, RAND P-2575; on Khan's drug use see Ghamaria Tabrizi, 75; Novak, S. 'LSD Before Leary', ISIS 88 1 1997, 110.

conceptual art performances:[26] New York based sculptor John Chamberlain had been granted access to RAND thanks the LA County Museum of Art, part of a project that invited forty local hi-tech industries to collaborate with cutting-edge artists. Chamberlain screened his semi-pornographic film *The Secret Life of Hernando Cortez* at lunchtime, interviewed strategists, and issued gnomic questionnaires to employees. But the artist complained that he had been unable to 'get into any of their circuits'. Attitudinally, he thought RAND staff were still 'very 1953'.[27] But his mere presence suggested otherwise, it manifest the Corporation's ongoing commitment to methodological exploration.[28] And as with many institutions at the time. the division between 'square' science and a 'groovy' counterculture appeared to have blurred.[29]

An Environmental Thinktank

Close readers of the Pentagon Papers learnt that RAND researchers had not only got mixed up in pacificism, drugs, and conceptual art, but also a distinct form of environmentalism. In 1967, Navy researchers at China Lake Aerial Ordnance Test Station, 150 miles North of L.A. in the Mojave Desert, had experimented with using airplanes to seed clouds with silver iodine with the aim of 'enhancing' rainfall. Part of classified 'Operation Popeye', the plan was to extend the monsoon season along the Ho Chi Minh trail so North Vietnamese combatants would be bogged down in a muddy quagmire.[30] Thanks to Ellsberg's leak this and other attempts to weaponize the weather were publicised by journalists Seymour Hirsch and Jack Anderson,

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[26] Pamela Lee, 'Aesthetic Strategist', 28-29; Wagley,
[27] Wagley, x.
[28] Lee, 29., and according to Sharon Ghamari-Tabrizi, RAND's Herman Kahn had long manifest an avant garde sensibility, see Ch. 2. The Cold War Avant Garde at RAND, in The World's of Herman Kahn.
[29] Kaiser and McCray Groovy Science, 2.
[30] James Rodger Fleming, Fixing the Sky: The Checkered History of Weather and Climate Control. Columbia University Press (2010) 178-179.

provoking public outcry and a Senate hearing.[31] Though not directly involved, since 1969 the National Science Foundation had tasked RAND with assessing the efficacy of these weather modification projects. With typical rigour their investigation noted significant gaps in basic scientific knowledge about weather and climate which inhibited their ability to assess whether weather had actually been altered by human interventions or merely run its course, and in doing so noted their 'growing respect for uncertainties and desire to unravel' the mysteries of atmospheric science.[32]

In 1963 RAND added an Environmental Services Department to its nine existing divisions.[33] The group expanded upon the work of the longstanding 'Planetary Sciences' department.[34] Its head, UCLA trained geophysicist Stanley Greenfield (1920) was a pioneer of balloon and satellite weather observation for the U.S. navy and weather bureau, he also led the weather modification study.[35] Early department work involved the development of models of precipitation and climate, partly to help the understand the implications of nuclear fallout but also to advance basic 'knowledge of how energy fluctuates among the various scales of atmospheric motion'.[36] In subsequent years, important simulations of atmospheric general

[31] Kristine Harper, Make it Rain: State Control of the Atmosphere. 230.
[32] Chunglin Kwa, 'The Rise and Fall of Weather Modification', Clark Miller, Paul Edwards, Changing the Atmosphere: Expert Knowledge and Environmental Governance, 147. Kwa quotes a 1969 RAND study republished as Staff, the Weather Modification Research Project of the RAND Corporation, 'Weather modification progress and the need for interactive research'. Bulletin of the American Meteorological Society, (1969) 50 4 216-247.
[33] Editor, 'Interview: Stanley Greenfield', Environmental Science and Technology (1971) 5 10: 990-992.
[34] The Planetary Sciences department was one of RAND's earliest, beginning as Geophysics in 1947 under the directorship of William W. Kellogg. On the history of planetary science see Doel, R. 'Theories and Origins in Planetary Physics", Isis 90 3 1999, 563-568.
[35] Greenfield's interest in satellites was piqued by Japan's use of paper balloons to float over the Pacific and drop incendiaries on the U.S. which indicated great expertise in understanding the dynamics of the upper and lower atmosphere. His plan for a weather monitoring satellite would be later realised with TIROS-1 the world's first successful weather monitoring satellite, 20-26. Davies, M., Harris, W. RAND's Role in the Evolution of Balloon and Satellite Observation Systems and Related US Space Technology. RAND Corporation, 1988, R-3692-RC.
[36] Greenfield, S. Huschke, R., Mintz, Y., Rapp, R.R., Sartor, J. (1962) 'A Rationale for Weather-Control Research', Transactions of the American Geophysical Union, 43 4: 469-489. 469.

circulation were developed at the Corporation and made their way to the wider scientific community despite being ostensibly confidential 'gray' reports.[37] Less conventionally 'environmentalist' were visionary if highly insensitive earth engineering schemes, such as a plan to build vast dams on the Congo river and the Ubangi tributary, to create a vast 1.4 by 10^6 square kilometre lake, as lake Chad filled the Congo basis. This move, according to their Mintz-Arakawa climate model, may have brought rain to the region but would have submerged ten percent of the African continent in water.[38] Unlike prior environmentalisms, such opportunities for amplified human agency were seen positively. By 1969, for Greenfield 'man' was no longer 'a small perturbation to the balance of nature' but its 'controlling influence', a position that required 'responsibility for the continued habitability of the earth'.[39]

RAND's environmentalism sought to both brutally instrumentalize nature and to better understand the intricacies of its processes. A third strand of environmentalism gradually emerged, one which recognised the potentially catastrophic effects of human led environmental change.[40] The think tank's interest in intentionally modifying the climate would lead to investigations into *inadvertent* climate change. Former Air Force meteorologist Joseph Fletcher (1920-2008), the first person to ever set foot at the North Pole, published a review of climate change research while at RAND in 1968, a year marked by unusually extensive sea ice and a what harvest so abundant that India ran out of storage space.[41] His review of climate change research

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[37] Weart, Spencer. "General Circulation Models of Climate", Archive: https://history.aip.org/climate/GCM.htm
[38] Rapp, R.R., Warshaw,W. (1974) 'Some Predicted Climatic Effects of a Simulated Sahara Lake, R-1415-ARPA; Greenfield, Stanley, Science and the Natural Environment of Man, (1969) RAND, 8.
[39] Greenfield, Stanley, Science and the Natural Environment of Man, (1969) RAND, 3.
[40] Darwin Hamblin introduces the term 'Catastrophic environmentalism', to described the segue between fears of atomic apocalypse to those of the environment, 8-9.
[41] On Fletcher at the North Pole see Digby, J. 'Early RAND: personalities and projects as recalled in the Alumni Bulletin', RAND Corporation, 2001, P-8055; on sea ice and wheat, Fletcher, J.O. Changing Climate. P-3933 2.

cited the now classic papers of engineer Guy Stewart Callendar (1938) and physicist Gilbert Plass (1959) who both argued that observed climate warming could be explained as a result of increased concentrations of atmospheric carbon dioxide. Fletcher's publication somewhat cautiously argued that 'man is probably inadvertently influencing global climate'.[42] More emphatically, drawing on the work of Soviet geophysicist Mikhail Budyko (1920-2001), Fletcher estimated that if energy demand continued to grow at its current rate (4 percent p.a.), in 200 years the 'heat pollution' it created would rival the heat of the Sun, an addition to Earth's energy budget that would cause 'sharp global warming' and 'reinforcing transformations' such as polar ice melt which would dramatically transform Earth's climate.[43]

RAND's environmental science department had fostered basic atmospheric science research and led to the formulation of a catastrophic scenario for the future of human energy use. This episode is remarkable not only for demonstrating RAND's growing concern over climate change, but also because it showed a willingness to engage with Soviet scientists.[44] As director of the Leningrad Geophysical Observatory in the late 1960s Budyko had developed a sequence of equations to model Earth's thermal balance. These showed how small increases in average temperatures would cause rapid polar ice melt via the albedo effect, triggering dramatic changes in mean global temperature leading him to warn of a 'coming climate catastrophe'.[45] The Russian geophysicist combined these models with an interest in 'the energetics of

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[42] Fletcher, J.O. Changing Climate. P-3933, 10-11,

[43] Fleming, 239, Fletcher, 1969, 11.

[44] Rinzivicuite notes the Soviet state planning committee, Gosplan, admired RAND and tried to develop its own thinktanks, such as the All-Union Scientific Institute of Systems Research (VNIISI) 27., extended research states for Russian scientists were not unknown. Soviet scientists Mikhail Lopukhin stayed at rand for almost a year in the late 1960s, later publishing a book on forecasting science. Rinzevicuite, Power of Systems, 242, ft. 3.

[45] Cited in Weart The Discovery of Global Warming, 86l On Budyko see Oldfield, Jonathan. "Imagining Climates Past, present and Future, Soviet Contributions to the Science of Anthropogenic Climate Change, 1953-1991", *Journal of Historical Geography* 60 (2018) 41-51.

man', at the time characterised by geometrical increases in society's rate of fuel consumption. Combining his thermodynamic model of the Earth system with this human behavioural propensity, in 1961 he had begun warning of an inevitably overheated planet. On the basis of this work, he as invited to both the University of California and RAND in 1966.[46] This event no doubt explained Fletcher and Greenfield's engagement with Budyko's prediction of a coming climatic catastrophe if society's use of energy continued to grow unchecked.[47] It also demonstrated a shift in the RAND Corporation's interest in climate change, shifting it from an intentional strategic objective to something to be averted for reasons of collective survival.

Energy Futures

A strange mix of cold war rationality and environmental concern was taking shape at RAND, and as ever, geography was important. Considered the last frontier of Westward expansion, California had a significant role in the early twentieth century nature preservation movement. Local organizations such as the San Franciscan Sierra Club, founded in 1892, had become a network of powerful nationwide lobby groups who fought for the protection of wild places and whose membership occasionally overlapped with the RAND payroll.[48] The double identity of such conservations became apparent when, in 1963, the Federal Bureau of Reclamation announced plans to construct a reservoir and hydroelectrical power plant at Marble Gorge, near Arizona's Grand Canyon. A concerned RAND economist Alan Carlin (1937-), a long-standing member of the L.A. branch of the Sierra Club, was contacted by Club director, conservationist David Brower (1912-2000) to more critically assess

[46] Weart, Budyko Oral History interview. AIP

[47] Fletcher, J.P. Proceedings of the Symposium on the Artic Heat Budget and Atmospheric Circulation, RAND Corporation, RM 5233 NSF, 1966.

[48] Wellock, Critical Masses, and Cohen, M. The History of the Sierra Club, 1892-1970, 320.

the development.[49] Opinion was split as to whether the proposed reservoir would be a landscape-enhancing lake or a destructive deformation of a unique natural monument.[50] Carlin soon let Brower know the cost-benefit analysis method the Bureau used was outdated.[51] Brower later commissioned Carlin to update the analysis, comparing the benefits of hydroelectricity to the projected costs of nuclear power, which the Atomic Energy Agency believed would be relatively cheap at the time.[52] Federal government was obliged to adopt the lowest cost solution to a given problem under the mandate of the 'Planning Programming Budgeting System', itself a RAND invention.[53] As a result, the Grand Canyon development halted and Carlin went on to argue that 'impartial' organisations like RAND had a role in assuring the cost and benefits of nature preservation were calculated with sufficient objectivity.[54]

The Growing Demand for Energy Project

On Carlin's recommendation, in July 1970 a group of RAND researchers received a grant from the National Science Foundation, which had recently asserted its commitment to problem-oriented research rather than basic science.[55] RAND management had sought to diversify into public policy.[56] In 1969 Schubert

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[49] Byron Pearson, Still the Wild River Runs: Congress, the Sierra Club, and the Fight to Save Grand Canyon. University of Arizona Press (2002) .94.

[50] Cohen, 321; A long-standing debate in the US conservation movement, see Righter, R. The Battle over Hetchy Hetchy, 2005.

[51] Pearson, 94; systematic CBA in public budgeting was considered largely a RAND invention, and stemmed from its Air Force work, Quade, E.S. A History of Cost-Effectiveness, 1971 RAND AD730430. See also Hoos, I Systems Analysis in Public Policy, 10. <<Novick 1965>>

[52] Pearson, 98, 129; Alan Carlin, William Hoehn, Is the Marble Canyon Project Economically Justified? (1966) RAND Paper, P3302. On the role of the Sierra Club in the Bodega Bay controversy, see Wellock, 31-32, and on Brower's later opposition to nuclear power, see 92.

[53] Jardini, in Hughes; see also Chassonnery-Zaïgouche, C., & Larrouy, L. (2017). "From warfare to welfare": Contextualising Arrow and Schelling's models of racial inequalities (1968–1972). The European Journal of the History of Economic Thought, 24(6), 1355–1387. doi:10.1080/09672567.2017.1381135

[54] Carlin, A. (1968) 'The Grand Canyon Controversy: Lessons for Federal Cost-Benefit Practices', Land Economics, Volume XLIV, No. 2, pp. 219-227.

[55] Mody and Turnbull *Forthcoming*.

[56] Jardini, Out of Blue Yonder, 1996.

committed the Corporation to six new areas of research, including 'environmental conservation and control'.[57] Deane Morris, a former aerodynamics and ballistics researcher, would lead the ten-person Energy Policy Program team. Recognising the incompatibility of forecast energy demand growth rates with the need to 'restore and preserve the quality of the environment', The Growing Demand for Energy (GDE herein) study intended to analyse 'the development of power systems in the context of the *total system'*, which meant the interrelation of resources, technology, society and the environment, the 'biosphere' upon which the whole enterprise depended.[58] The proposal had three goals: to 'identify and quantify' factors which determined overall demand; to 'develop methods of relating these factors'; and to use this data and its relations to create a family of models to account for 'alternative policies and uncertain future events.'[59] By approaching the question of energy demand *systemically* rather than as a discrete set of problems it was hoped the project could identify unaccounted for environmental, social, and regulatory dynamics which determined growing collective energy use rates and the prosperity that came with it.

The GDE work was underwritten by a growing sensitivity to social concerns, as it was suggested, demand forecasts could not simply extrapolate from technological trends, because if 'technology brings about changes in society, it is equally true that social conditions and cultural values influence the uses to which technology is put.'[60] Such statements sought to acknowledge and quell a wider sense of criticism. A contingent

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[57] Jardini, Thinking through the cold war, 256.

[58] The original application is not available, but this working note provided 'the substantive part' of the first proposal. Morris, D., Doctor, R., Mooz, W. (1971) Proposal for Continuing Work on The Growing Demand for Energy', WN-7357-NSF, March. NSF, RAND Corporation. Working Note.16l on biosphere dependencies see WN-7358, p. 116.

[59] Ibid, 1.

[60] Morris, D.N., Doctor, R., Mooz, W. (1971) The Growing Demand For Energy. WN-7357-NSF, 3.

of Californian society seemed to have turned against reason. Berkeley historian Theodore Roszak (1933-22011) described young peoples' growing belief in the 'myth of objective consciousness' and University of California physicist turned historian Paul Forman later described a more general 'resentment and antagonism toward the scientific enterprise' amid a growing counter culture.[61] Seemingly responding to such low opinions of their *raison d'être*, RAND's 1971 *Annual Review* noted how 'critics of rational approaches properly observe that science and technology have put men on the moon but have not ended war and injustice; systematic analysis has not curbed urban blight nor the growing pollution of land, air, and water' – but, there, their self-admonition ended: it would be a 'serious error to give up rationality' as it was vital to addressing society's problems. But pure reason was not sufficient; analysts should show humility and recognise that 'wisdom is our most scarce national resource'.[62]

If wisdom was in scarce supply, energy was abundant. Even before the GDE project began, Greenfield had been sufficiently concerned by Budyko's work on heat pollution that he had attempted to calculate his own estimate of wasted thermal energy at a planetary scale in December 1970. He had qualified his efforts because of the crudeness of most energy demand projections, which relied 'almost exclusively on pure extrapolation from the past'.[63] However crude the underlying method, Greenfield's estimate revealed an untenable situation. The amount of global thermal waste was assumed to increase by 5.7 per cent year, creating more than 31 million megawatts of wasted energy by the year 2000. The U.S. electrical growth rate of 4

[61] Roszak, T. (1968: 211) The Making of a Counter Culture: reflections on the technocratic society and its youthful opposition. Doubleday, New York; Forman, P. (1971) 'Weimar Culture, Causality, and Quantum Theory, 1918-1927: adaptation by German Physicists and Mathematicians to a Hostile Intellectual Environment', Historical Studies in the Physical Sciences, Vol. 3, 7.
[62] RAND Corporation, Santa Monica, California, 1971 Annual Review , 1-3.
[63] Greenfield, S. (1970) Projection and Distribution of Waste Thermal Energy, RAND Corporation, P-4540, p. 1.

percent per annum suggested energy use would double by 1988.[64] Greenfield's second observation was that such forecasts 'tend to be self-fulfilling'. Given the lead-time required to build 'generation hardware' such as power plants, construction could begin as much as fifteen years before forecasted demand was needed. Fifteen years later, with that extra power now available, it would inevitably be consumed. In succinct prose characteristic of RAND, Greenfield argued that as a result, 'projected demand leads to the creation of the forecast capacity'.[65]

Greenfield's criticisms could have been expected. Forecasting was a RAND speciality. From John von Neumann's use of eighteen-thousand vacuum tube computer to produce monthly weather forecasts during the Manhattan Project, to the 'Delphic' interview methods of Olaf Helmer and Theodore Gordon, the future was seen as an object of research which could be investigated with empirical and methodological rigour on a par with that of the natural sciences.[66] Helmer and Gordon's colleague, philosopher-mathematician Nicholas Rescher could later credibly claim that in the 1950's and '60s RAND developed most of the technological and social forecasting methods that would become widely used in a variety of global institutions during the futurological boom of the 1970s.[67] Such methods were not intended to be acts of pure divination so much as means for creating alternative futures, particularly as forecasts could be used as persuasive justifications for intervening in the present.[68]

[64] Ibid, p. 4.
[65] Greenfield, 1970, 1.
[66] Andersson, J. (2012) 'The Great Future Debate and the Struggle for the World', American Historical Review, Vol. 117, Iss. 5, pp. 1411-1430. Helmer, O., Rescher, N. (1958) 'On the Epistemology of the Inexact Sciences', RAND Corporation, P-1513.; on Helmer see Kaplan, .62; Nicholas Rescher (1997) 'H2O: Hempel-Helmer-Oppenheim, an Episode in the History of Scientific Philosophy in the 20th Century', Philosophy of Science, 64 2: 334-360. 352; Rescher, N. The Future as an Object of Research. RAND P-2593.
[67] Rescher, 1998 Predicting the Future: An Introduction to the Theory of Forecasting. SUNY Press, 28.; Gramelsberger et al ref; see also Nicholas Rescher (1997); Andersson, J., Rinzivicuite, E. The Struggle For the Long-Term in Transnational Science and Politics: Forging the Future. Routledge.
[68] Andersson, J. The Future of the World, (2018), 78.

Great accelerations in rates of energy and resource use are now recognised as a characteristic of the post-war period, particularly in U.S.[69] But the role models had played in contributing to such growth has not yet been given due consideration. Seemingly inexorable growth in the use of energy challenged an almost unspoken belief on both sides of the post-war world: that prosperity went hand in hand with increased energy use. Because if, as Budyko had predicted, society's increased rate of energy use would eventually destroy Earth's climatic stability, then the benefits of ever-more energy consumption had clear limits. Given Greenfield's belief in the performative role that energy demand forecasts played in helping construct future energy demand, six months later, the GDE project would hypothesise that better forecasting would not only increase the accuracy of future estimates, they could also potentially help to modify the growth rate of society's electrical energy demand.[70]

Earlier work by RAND economist William Hoehn on the economics of nuclear power had noted how the Atomic Energy Commission's (AEC) plans for supporting new plant directly or indirectly depended on the Federal Power Commission's (FPC) National Power Survey. Both organisations, Hoehn concluded, tended to use 'upper estimates' of future demand, based on 'a very dubious set of assumptions' with regard to population growth, per capita electricity demand, and the quantity of power anticipated to come from nuclear.[71] Since 1935 the FPC had created its annual estimate of future power demand largely by collating individual demand forecasts from utility companies. In line with New Deal logics, the aim had been to allow

[69] Lane American Anthropocene, x

[70] Morris, D, Anderson, K., Doctor, R., Mooz, W. Proposal for Continuing Research on the Growing Demand for Energy, RAND Corporation, WN-7539-NSF 23.

[71] Hoehn, W. (1967) The Economics of Nuclear Reactors for Power and Desalting. RM-5227-1-PR/ISAM, 76-86.

Federal coordination of investment and planning in an industry that had expanded beyond state boundaries and was increasingly dominated by private commercial interests.[72] By 1970,increasingly concerned about the 'unusual stresses' imposing themselves on the electricity industry, the Federal Power Survey surveyed a number of utilities to assess how they carried out their long-term forecasting: half simply extrapolated from the past, used compound growth rates, or constructed a fitted curve. Others interviewed consumers or analysed land use and census data, while the more sophisticated attempted correlations with variables such as GNP, and a quarter simply did not bother long-term forecasting at all.[73] In aggregate, it was such forecasts which underlay the FPC's dramatic estimates of increased energy demand.

GDE researcher William Mooz was as unimpressed as Greenfield with these forecasting efforts. Having examined the composition of California's electrical energy demand forecasts, he questioned 'the objectivity of projections by those whose prince interests are the marketing of their product'.[74] Often outdated and simplistic, utility forecasts made little or no concession to economic theory: electricity was by and large considered insensitive to price changes. This was partly because the FPC was obliged by law to ensure the provision of electricity below assumed market cost, as a means of compensating consumers for the natural monopoly created by their state and Federal granted right to operate non-competitive franchises in a given region.[75] This contributed to the fact that advances in econometrics, particularly regarding

[72] Cantelon, 67.
[73] This refers to the total number of companies involved in the industry, of these around 1017 were generating power, the FPC carried out a representative survey of just 30 utilities. Technical Advisory Committee on Load Forecasting Methodology. Report to the Federal Power Commission, 1969. IV-4-38-39
[74] Mooz P-4956, 1-3. The Californian Public Utilities Commission required each of the 5 major utilities operating in the state to annually file ten-year estimates of forecasted electricity demand.
[75] Hirsh, Power Loss, 11.

price elasticities, were largely disregarded.[76] While the use of computers to manage of grid operations had only been patchily implemented.[77] Those familiar with such advances appreciated that they would add a robust probabilistic element to forecasts by allowing multiple projections and accounting for myriad changes in underlying variables.[78] But as it was, Mooz concluded that a combination of artificially low-cost electricity, a booming post-war population, new electrical appliances, and steady rate of economic growth, had created an energy demand situation in which ‘anyone with a ruler and some data plotted on semi-logarithmic coordinates could provide the information required’ to more-or-less accurately forecast energy demand.[79]

A very fundamental reason for this was that exponential growth had long been considered vital to the success of electrical system. Understood in socio-technical terms, the supply and use of electricity as an economical technology was predicated upon increases in the amount of electricity consumed, the scale of interconnection, economies of scale, and the efficiency of conversion. Given the high fixed costs of electricity provision and its relatively low operating costs, the closer the average rate of use was to the peak load that a grid could withstand, the lower the cost of a kilowatt hour of electricity (the so-called ‘load factor’).[80] Historian Richard Hirsh described how since the earliest days of the industry, this intersection of economic rationales and technological affordances created a ‘design by extrapolation’ model of electricity provision; a cornucopian consensus encapsulated in the 1964 FPC Survey

[76] REF
[77] Cohn 2015 Transitions from Analog to Digital Computing in Electric Power Systems,
[78] Technical Advisory Committee on Load Forecasting Methodology. Report to the Federal Power Commission, 1969. IV-4-48-49, Cohn 2015, cites one engineer ‚the digital machiens are desinged to do many arithmetical computations at high speed, while the analogue in some ways forms a model of the actual system‘, 37.
[79] Mooz, B. P-4956, 1-5. Mooz, 1973: 273
[80] Hirsh, Technology and Transitions, 17-18

as utilities' shared commitment to development of 'new and larger units, employing higher temperatures and pressures' in power generation.[81]

Visionary Engineering

Limits to ever-growing electrical energy demand rates were already becoming clear by the late 1960s. Locally, the development of increasing numbers of increasingly large power plants had begun to invite local opposition from those looking to preserve California's last areas of wilderness.[82] Utilities themselves recognised the near insurmountable technical problems involved in meeting projected growth rates.[83] Five years early a transmission line conveying power from Niagara Falls had cut out, causing a circuit imbalance and a chain-reaction of trips that resulted in the largest blackout in the nation's history.[84] Worse still, steady increases in the efficiency of electrical power generation had reached a point of technological stasis, with thermodynamics now imposing a limit to the heat at which steam could be directed at a plant's turbines; as a result, steady decreases in the unit cost of electrical power that were characteristic of the post-war period could no longer be assured.[85] Worse still, the past two summers had been marked by brownouts and winter fuel shortages. The National Environmental Policy Act of 1969 introduced restrictions on burning sulphurous coal for power generation, causing anthracite and bitumen prices to rise.[86] At the time, 67 percent of U.S. electricity came from coal.[87] Many more biospheric constraints were anticipated. RAND's Earth Sciences

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[81] Hirsh, Technology and Transition, 63.
[82] Wellock, Critical Masses, 17-68; Hirsh, Powerloss, 68.
[83] Chapman, D., Tyrell, T., Mount, T. (1972) 'Electricity Demand Growth and the Energy Crisis', Science, Vol. 178. No. 4062, pp. 703-708.
[84] Gordon Friedlander, 'The Northeast power failure – a blanket of darkness', IEEE Spectrum (1966) 3, no. 2: 54-73. Cohn, .157; Nye, When the Lights Went Out, 28-29.
[85] Hirsh, 89; FPC, 1970, x.
[86] FPC x.
[87] FPC, 1970 1-1-15.

department drafted tables to show how energy demand would be constricted by the limited affordances of the atmosphere, hydrosphere, and lithosphere.[88]

Growing energy demand also presented a spatial problem. Bodega bay, fifty miles north of San Francisco had been one of the first flashpoints. Its wide bay, fringed by green hills would be the location for Alfred Hitchcock's *The Birds* (1963). But in 1958 the granite peninsula had been scouted by Pacific Gas and Electric as a secure site for a nuclear plant. The site was preserved thanks only to the concerted efforts of a mix of landowners, anti-nuclear activists, environmentalists, and seismic risk.[89] But further incursions along the coast seemed inevitable. By the late '60s Sacramento State engineering professor Charles Washburn (1937-2009) calculated that if electricity demand increased as the FPC predicted, by the year 2020 the constraints imposed by the built environment, seismic activity, and the need for coolant would mean there would be a 1000 MW nuclear plant at every two-mile interval along the state's entire coastline; an area which, just two centuries earlier, had been one of world's remotest places.[90] RAND staff would propose imaginative technological fixes to avert this outcome. In January 1972, mechanical engineer Richard Salter suggested constructing powerplants on buoyant platforms anchored in the Pacific. His proposed *Floating Offshore Power Platform*, with the unfortunate acronym FLOPP, described a network of twenty-five almost fully submerged 'pop bottle' shaped powerplants that would use seawater as coolant and protection against seismic activity. Assembled in clusters of seven to create a network structure which would 'minimize the probability of joint interruption', generated electricity would be

[88] WN-7358 117-119.
[89] Wellock, 17-18.
[90] Salter, 1972: 1; Salter to Hogan, Disclosure of FLOP, 13 March, 1972, Memorandum.

conveyed to three transmission terminals and then onshore via undersea cables.[91] At the time,, another Airforce spin-off, the Aerospace Corporation, was investigating underground reactors.[92] Such visionary engineering demonstrated the exploratory approach RAND and other Californian organisations adopted in the face of limits.[93]

Systems Dynamics

No less visionary, in 1971 RAND mathematician Fred Roberts would employ a considerably easier to manipulate form of network to address growing energy demand. While conservation education chairman of the LA branch of the Sierra Club in his spare time, at work this Stanford trained mathematician had become a combinatorics specialist, addressing the mathematical dynamics of finite structures. He proposed using a branch of combinatorics called graph theory to understand energy demand as an outcome of a dynamic system of interrelated dependencies rather than linear system of supply and demand.[94] As far back as in 1763 Swiss mathematician Leonard Euler had used such thinking to try to find the shortest route over the seven brides of Königsberg. Though a trivial problem, Euler begun developing topological methods for optimising decisions in a constrained physical

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[91] Salter, Disclosure of Invention, <<See Archive fotos>>, Doctor, R. The Growing Demand for Energy, January 1972. RAND P-4759, 4.>> A network structure, designed to ‚minimize the probability of joint interruption by a common hazard', much like Paul Baran's network communication structure, also developed at RAND. Light, J. (2003) From Warfare to Welfare: Defense Intellectuals and Urban Problems in Cold War America. Johns Hopkins University Press. Baltimore, 163.

[92] Watson M., Kammer, W, Kangley, N, Selzer, L, Beck R. Underground Nuclear Power Plant Siting, Environmental Quality Laboratory Report 6, California Institute of Technology, Pasadena, CA. 1972, RANN.

[93] In fact, a year earlier two utility companies, Westinghouse and Tenneco formed a joint venture, 'Offshore Power Systems', planning to create floating nuclear reactors of the coast of Jacksonville Florida, though the project was abandoned by the decade's end. Wellock, T. 'Waves of Uncertainty: The Demise of the Floating Reactor Concept. Public-blog.nrc-gateway.gov, 2013; on visionary Californian engineering see McCray, P. (2012) 'California Dreamin': Visioneering the Technological Future, in Minds and Matters: Technology in California and the West, Volker Janssen, ed. University of California Press, 7.

[94] Morris, D. Interim Report: The Growing Demand for Energy, RAND Corporation, WN-7358-NSF. 138; RAND Biographical Archive, Fred S. Roberts (1943).

world.[95] Robert's aim was to use a similarly constrained topology to model the major constraints acting on the energy economy which would not only represent its known dynamics, it could also be used to test the effect of changes to these dynamics, such as imposing regulations on pollutant emissions or taxes on consumption.[96]

Roberts' proposal was that all of the major determinants of energy demand should be represented as nodes, related to other nodes via edges.[97] Edges were directional, in so far as a node's agency acted upon a specific node, a variation in its value would have a quantitative effect on the value of another node, either positive or negative. Digraphs, the GDE team noted, were related 'to other techniques for analysing systems' such as simultaneous equations, input-output analysis, linear difference equations. But digraphs had a 'psychological' benefit over these methods, as they represented relations in an intuitive way. Moreover, adding new nodes, new feedback loops, or changing of signs or edges offered analysts 'a precise way to generate new policy alternatives and, at least qualitatively, to evaluate their effectiveness'.[98]

Robert's proposal was of its time, feedback had become characteristic of many disciplines in the '70s.[99] But rather than drawing on the conventional cybernetic subject of homeostasis, Roberts described his work in terms of 'second cybernetics', the study of systems that amplified a deviation from a given condition. Japanese systems analyst Magoroh Maruyama (1929-2018) had published a 1963 paper in

[95] Harary, 1.; Biggs, N., Lloyd, K., Wilson, R. (1976 [1986]) Graph Theory, 1736-1936. Oxford University Press.
[96] Deane Morris, Interim Report: The Growing Demand For Energy (1971) WN-7358-NS .9
[97] Nodes and edges were ascertained via the Delphi Technique via a panel of experts, or as Robert's termed it 'subjective judgements of groups of experts', Roberts, F. (1972) Building an Energy Signed Digraph I: Choosing the Nodes. RAND Corporation, R0927/1.
[98] Morris, D. Interim Report: The Growing Demand For Energy, RAND Corporation, WN-7358-NSF 138.
[99] Belgrad, D, The Culture of Feedback, 30-31.

American Scientist which argued that analysts had focused on deviation reducing systems for too long, and this was a mistake given the greater ubiquity of deviation amplifying systems, not least *capital accumulation, evolution, and erosion*.[100] In an energy system, a majority of negative feedbacks meant growth in energy demand would reduce as 'deviations are counteracted', whereas a *majority of positive feedbacks* would mean 'deviations are amplified' and growth in energy demand would increase.[101] Roberts' goal was to therefore to work against growing deviation in energy demand, to achieve an increasingly homeostatic rate of increase.

To demonstrate, in the pictured example, an increase in energy use (U) would decrease the quality of the environment (Q), which would counter deviation between the nodes (edge U, Q = - n). Whereas an increase in energy use (U), would increase the population (P), which would lead to deviation amplification over time (edge, U, P = + n). Though the model was simple, given that the U.S. rate of energy demand was increasing, Roberts could safely hypothesise that the complex reality of the energy system was in some sense similarly structured, and that the addition of 'deviation countering sub processes', such as a more efficient technologies, or taxation, both in the model and in the system at large, could, he hoped, help stabilise the rate at which increases in energy demand rate deviated from prior levels.[102]

In concluding his study, Roberts admitted digraph models were imperfect and that whatever the level of complexity 'you never know for sure' if a variable had been

[100] Maruyama, M. (1963) 'The Second Cybernetics: Deviation-Amplifying Mutual Causes', American Scientist, Vol. 5, Iss. 2, pp. 164-179

[101] Roberts, F. (1971) Signed Digraphs and the Growing Demand for Energy. RAND Corporation. R-756-NSF.

[102] 'a system is called stable if the value of no variable gets larger and larger in any situation which some external change is introduced at some other variable'., Roberts, F. (1976) 'Strategy for the Energy Crisis', in Axelrod, R. Structure of Decision: The Cognitive Maps of Political Elites. Princeton University Press., p. 168

omitted.[103] But as Olaf Helmer had suggested back in 1958, a certain inaccuracy was characteristic of all sciences. The greater goal was that simulations should reveal 'specifically predictive instrumentalities' upon which effective policy decisions could be made.[104] Robert's aim was not realism nor comprehensiveness but pragmatic outcomes. Compared to the extrapolations of the utility industry, his abstract model, however simple, provided a more dynamic, systemic representation of energy demand. Moreover*, it implied the system of energy demand could, in a sense, be programmed*. If the graph represented reality, the *material* infrastructure of energy use could be reconfigured to have an odd number of negative feedbacks, or to have new loops, so the system would iteratively reduce increases in the energy use rate.

California's Quandary

What were the implications of RAND's systematisation of energy demand? At a cocktail party in 1971, Emilio Varanini, a lawyer at the California State legislature, met members of the GDE project. This convivial meeting resulted in an agreement that RAND researchers would use their growing expertise to model the state's energy use.[105] The California State Resources Agency (CSRA) contributed funds to RAND's existing research program and the study began.[106] At the time, utilities from Pacific Gas and Electric, to Southern California Edison, and San Diego Gas and Electric were warning the California state legislature that blackouts were imminent **(21).**[107] The state's post-war prosperity indicated that electrical capacity would need to double

[103] Roberts, 1976, p. 28.
[104] Helmer, O., Rescher, N. (1958) p. v.
[105] Wellock, 1998, p. 138
[106] Mooz, W., Mow, C. (1972) The Growing Demand for Electrical Energy in California, RAND Corporation, RIOB4-NSF/CSRA.
[107] Lifset, R. (2014) 'Environmentalism and the Electrical Energy Crisis' Lifset, R. ed., American Energy Policy in the 1970s. University of Oklahoma.

every 8.5 years, a growth rate that would theoretically outstrip the ability of society to finance, build, and even find room for the generating facilities – to say nothing of supplying them with fuel and their impact on the environment'.[108]

To address this quandary, RAND researcher Ronald Doctor led a team to create a computerised version of Roberts' model. The model would represent the state energy system numerically, and it would carry out a time-stepping procedure to simulate the system's behaviour over time. Researchers William Mooz and C.C. Mow gathered a vast range of empirical data that described aspects of California's economy, meteorological conditions, population density, and granular variables such as the energy efficiency of individual appliances. Sharon Anderson then programmed a computer model which structured this information in a relational manner representative of the known dynamics of the energy system.[109] Written in FORTRAN IV and run on an IBM 360/65, the model represented Californian energy demand as a series of industrial, commercial, agricultural, and residential sub-models. Residential electricity demand, for example, was calculated as a function of demography, appliance 'saturation', climate, housing type, electricity cost, and price structures. Variations in appliance use were also simulated based on energy efficiency, use rates, and ownership levels of known air conditioners or televisions, all with the aim of representing the system's dynamics with sufficient realism that alternative energy policies could be tested *in silico*.[110]

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[108] Mooz & Mow, 1972.

[109] Anderson, S. (1973) A Methodology for Projecting the Electrical Energy Demand in California: A Users Guide to the Model. RAND Corporation, R-1107-NSF/CSRA

[110] Doctor, R. (1973) Energy Demand in the Future - Reducing the Growth rate, RAND Corporation, P-4992; Anderson, 1973, p. 1.

Each run of the model required just 64 kilobytes of processing power and could be carried out in thirty-two central processing unit (CPU) seconds, meaning running the program through the hardware was relatively quick and inexpensive.[111] Such detailed modelling had only recently become possible, as increased processing power and lower hardware costs radically decreased the unit cost of computing in the '70s.[112] Now the operation of every new energy-efficient appliance in every home, factory, or office could be could be modelled, and could even be cast as a deviation *countering* sub process: in so far as it could be modelled to be more efficient than the device it was replacing, Each more efficient appliance could therefore act to stabilize rather than increase demand. In effect, the model was advanced enough to show how limits to electrical demand would be reached: residential energy use would 'taper off' as households became saturated with appliances, and industry would be return to 'manpower' rather than electricity beyond a certain point. In total, the model showed California using 196 billion *less* kilowatt-hours than utility companies predicted.[113]

More dramatic still, the model demonstrated how such reductions in energy use need not be at the expense of economic growth. Doctor and his colleagues devised scenarios which simulated the effect of policies that would slow California's demand for electricity beyond the 'base' model while not effecting the total utility derived from electricity: proposals for using gas instead of electricity, insulating homes, and improving appliance efficiency, and were intended to be limited so as to not interfere with the market's own allocative capacities. It was argued the annual growth rate for electricity demand could be reduced from 5 to 3 percent, eradicating the need for

[111] Central Processing Unit cycles per second. i.e. the number of times a computer can compute a set of instructions in a given second.
[112] Erickson 'The Bounded Rationality of Cold War Operations Research', in Erickson, P et al. 2013.
[113] Mooz & Mow, 1972, p. 24

over 100 power plants by the year 2000.[114] One Californian assemblyman called the report 'political dynamite' as it entirely undermined the case for new nuclear power plants.[115] Doctor had also proposed that the Californian state legislature create a new institution to coordinate 'all energy conservation policies.'[116] A 500 person California Energy Commission (CEC) was established.[117] Arguably, this helped California to go on to become, per capita, the most exceptionally energy efficient of U.S. states.[118]

For RAND, the energy project prompted institutional self-reflection. Bill Mooz wrote to Ronald Doctor in March 1972, pointing out that this work would likely 'call the public's attention to RAND' and that any perceived misalignment between the organisation's recommendations and its practices as a place of work risked opprobrium. Mooz noted that RAND did not recycle the 'copious quantities of recycled paper' its analysts went through, instead paying 'a truck collection to take it to fill in canyons in the Santa Monica mountains'. Whether institutional posture or heartfelt intention, Mooz advised the formulation of policies 'regarding office lights at night' and that, when it came to energy and resources, RAND should 'put our money where our mouth is'.[119] The archetypal Cold War think tank had become concerned with the environment, and with it, the environment had been recast as a system that could be optimise like the bombing campaigns of the B-29. The science spread of the science of saving energy marked, in effect, the application of cybernetic

[114] Doctor et al, 1972, p. vii
[115] Wellock, 1998, p. 140.
[116] Doctor et al, 1972, p. xiv.
[117] Wellock, 1998, p. 13.
[118] Rosenfeld H. & Poskanzer. "A Graph is Worth a Thousand Gigawatt-Hours: How California Came to Lead the United States in Energy Efficiency." *Innovations Case Narrative*: The California Effect. 2009.
[119] Mooz papers, RAND Corporation Archive, Letter from Bill Mooz to Don, 10.3.1972,

principles to the energy and resource flows of public and private life, in an attempt, as Norbert Weiner once stated, 'to create islands of order in a sea of entropy'.

Conclusion

At the height of World War Two, the Bavarian comedian Karl Valentin (1882-1948) once told the following joke:

"I read in the newspaper that there is a great gasoline shortage. No wonder! The Germans refuel their planes, load them with bombs, fly to England, drop the bombs, and fly back. How much petrol is consumed? What do the English do? They also refuel their planes, load them with bombs, fly to Germany, drop them, and fly back, also using a lot of gasoline. Wouldn't it be much easier, if the German planes would only fly over Germany and drop their bombs there, and the English planes would only fly over England and drop their bombs there. The success would be the same. But how much petrol would have been saved?"[120]

Like many subversive jokes, a logical idea, fuel economy, was taken to its ultimate and absurd conclusion. Valentin highlighted the disjuncture between two nations careful attempts to save fuel in pursuit of the wider goal of the other's annihilation. Increments of fuel efficiency were a subset of a hunt for marginal increases in the efficacy with which bombs could be dropped, with each advance allowing an increased payload or the extension of the radii over which they could be carried. It's not clear what Valentin would have made of the efforts made to ensure fleets of up to a thousand B-29 bombers could leave California and other U.S. bases in optimised volleys, using the occupied and terraformed Pacific islands of Guam, Saipan, and Tinian as stepping stones from which to refuel, before heading to Japan. Having travelled 3000 miles, the 140,000 lb planes would, in total, drop twice the monthly tonnage of bombs that had ever been dropped on German cities. These same B-29's

[120] The joke is relayed in Fritz Korner *Aller Tage Abend*, thanks to Benjamin Steininger for introducing me to the joke, 90-91, Klose and Steininger, *Erdöl: Ein Atlas der Petromoderne*. 90-91. <<Benjamin suggests thinking about the fact that the US did in fact bomb itself, and built not only fake American cities, but fake German cities

would also drop atomic bombs on Hiroshima and Nagasaki.[121] Guam would remain a U.S. possession, allowing bombers headed to South East Asia to refuel, and with even greater efficiency, drop more bombs during the 1960s than in all previous wars.[122]

RAND researchers had systematically analysed all aspects of the B-29 bomber sorties over Japan, looking to optimise the allocation of armour, bomb-load, and fuel efficiency to maximise the technology's destructive potential. By the early 1970s the same rigorous and systematic reasoning was applied to the various components that contributed to the state of California's rate of energy demand. Systems analytical models of industrial, commercial, and domestic energy use showed how it might be possible to optimise energy consumption while still retaining economic prosperity; to *decouple* energy use from economic growth, to remove heat from light. For a later generation, the lesson of such models would be that prosperity could be divorced from growth in energy. What Mike Davis calls 'spontaneous decarbonisation' as a by-product of economic growth.[123] The belief that increased energy efficiency causes an aggregate decrease in overall energy consumption is now a central pillar of climate change mitigation policy, with the relevant field of operation now extended to not just California, but the entire planetary atmosphere. *In Vitro* California is upheld as a model of successful and efficient energy use, but the problem, as it stands, is that California is not the world, nor is it a closed system, and much lies beyond an abstracted closed system of simulated optimisation of energy use.

[121] United States Air Force, The Last Bomb. B-29 super-fortresses over Japan. United States War Department, Documentary Film, 1947.
[122] Edwards 137,
[123] Davis, M. Who Will Build the Ark? 1