Reviews

Paul Michael Grant

Keeping the lights on after 2100

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Bright-light city Robert Laughlin's new book looks at the options for fuelling our energy consumption.

Powering the Future: How we Will (Eventually) Solve the Energy Crisis and Fuel the Civilization of Tomorrow
Robert B Laughlin
2011 Basic Books
$24.99hb 224pp

As the presidential election campaign hots up here in the US, it is inevitable that energy issues will loom large on the political agenda. Being Americans, our focus will inevitably be local and short term, although I admit to hoping that maybe – just maybe – this time around, politicians on both sides will finally tell the public what they mean by "clean energy". Right now, I haven't got a clue.

Putting such limited optimism aside, however, it is clear that energy strategies for the future will pose challenges far beyond the next election (and the next, and the next…), and not only for those of us living in North America. By the year 2100 our planet's population will exceed 10 billion souls, all striving for a North American or European standard of living, with its attendant thirst for energy. This is a staggering (and likely unsustainable) prospect, but it is just this scenario that the Stanford University physicist and Nobel laureate Robert Laughlin addresses in his book *Powering the Future*.

As with any complex and fundamentally nonlinear physics problem, the devil is always in the details. Fortunately, Bob Laughlin is a details kind of guy. His subtitle, "How we Will (Eventually) Solve the Energy Crisis and Fuel the Civilization of Tomorrow", tells us who that devil is, and that he or she resides within the parenthetical remark "eventually". Through 11 chapters and accompanying notes (which make up half of the book's total 224 pages), Laughlin guides us through the jungle of the energy economy: from coal to its combustion; gas to gasoline (petrol); fission dynamite to deuterium fusion; the transport of energy by electrons and protons; the possible future generation of electricity and fuels from waste substances such as manure and maize husks; and prospects for exploiting sources of energy that stem from cosmic radiation or pressures from within the ocean depths.

All of these processes are governed by a "Jungle Law", the title of Laughlin's third chapter. This chapter resonated with me personally, as it reflects my own metamorphosis from an industrial basic-research physicist to someone concerned with energy and the environment. Determining the direction of the energy enterprise is not like creating the market behind the next iToy, where scientific and technical matters are paramount. With energy, science plays at best a 50% role, the remainder being driven by raw economics skewed by political and social perceptions. Realizing this was an epiphany indeed.

Laughlin gives readers a great example of such an energy epiphany in his chapter on "Carbon fever". Seven decades ago, Linus Pauling taught us the marvels of the 2s–2p hybridization of carbon's outer shell, which lie behind all of the element's subsequent manifestations, from life to locomotion. Laughlin points out that the economics and physics of energy production from loosely bound carbon – in whatever form it is found, whether mineral, gaseous or organic – is overwhelmingly favourable compared with those of other "alternatives". Because of this simple fact, it is very likely that we humans will continue to oxidize pretty much every atom of available number six we can find.

Fortunately, there is a lot of mineral and organic carbon around, and this is likely to remain true at least for a while. A problem may arise in dealing with the element's greenhouse-gas form, carbon dioxide, although some economists have argued that the wealth created and banked by using fossil fuels to their limit could underwrite whatever climate-change adaptation technologies may be needed in the next century. Regardless of your views on carbon dioxide and climate change, though, we are likely to run out of the useful forms of cheaply available carbon sometime in the next 40–60 years. Then what? The first half of this book provides some hints of the answers, and for that reason alone, it should be mandatory reading for the next president of the US and their cabinet, and for those who follow – even if one or more of them does possess

a Nobel Prize for Physics.

For readers who do not have enough time for the entire book, let alone Laughlin's extensive endnotes (which, though great for physicists, can be tedious for non-specialists), I strongly recommend at least perusing the chapter "Inspiring mammoths". The title is a Laughlin-euphemism for nuclear energy of any origin, and in the chapter he explains that the chief economic barrier to a renaissance of nuclear-fission power is the expanding availability of coal and natural-gas reserves worldwide. There are other hurdles too, but they are mostly political and environmental in origin. The political argument against nuclear fission encompasses some sound concerns, such as weapons proliferation, and Laughlin suggests that these should be addressed by international enforcement, not just agreement. The environmental arguments, in contrast, essentially stem from a lack of proper perspective. It is instructive to point out that the death toll from a single commercial airline crash is approximately twice that of the confirmed number of radiation-exposure deaths from every nuclear-plant disaster to date, including Chernobyl and Fukushima. As far as we know, the toll from the latter remains zero (May pp25–28).

Concerns about running out of "burnable" fission material – for example uranium and thorium ore – seem likewise overblown based on Laughlin's analysis, which also covers issues of waste, reprocessing and "breeding" fissile material in specialist reactors. Given the vast amounts of uranium and thorium in the earth and the sea, the extension of such supplies through deployment of the above technologies, and the economic drivers that will come into play with the soaring costs of exploiting disappearing fossil reserves, my "take home" message from *Powering the Future* is that uranium and thorium nuclei will probably be the source of the parenthetical "eventually" in the book's subtitle. What about fusion? Well, judging from Laughlin's "Inspiring mammoths" chapter, fusion could indeed be the energy of the future – but it will likely remain so for a long time.

Those of us who are personally acquainted with Bob Laughlin know him as a colourful character. In New York, where I grew up, we would call him, warmly, a "wise guy". It is just this delightful attitude that makes his book so readable, and I can think of no better way to illustrate this than to quote his words in the book's closing sentences. After thoroughly exploring present and foreseeable energy resources for humanity, Laughlin ends with a prosaic, but most profound, warning that "The most terrible cosmic explosion of all will occur if I show up late again for dinner. It might be a good idea to stop worrying about the universe and hustle home."

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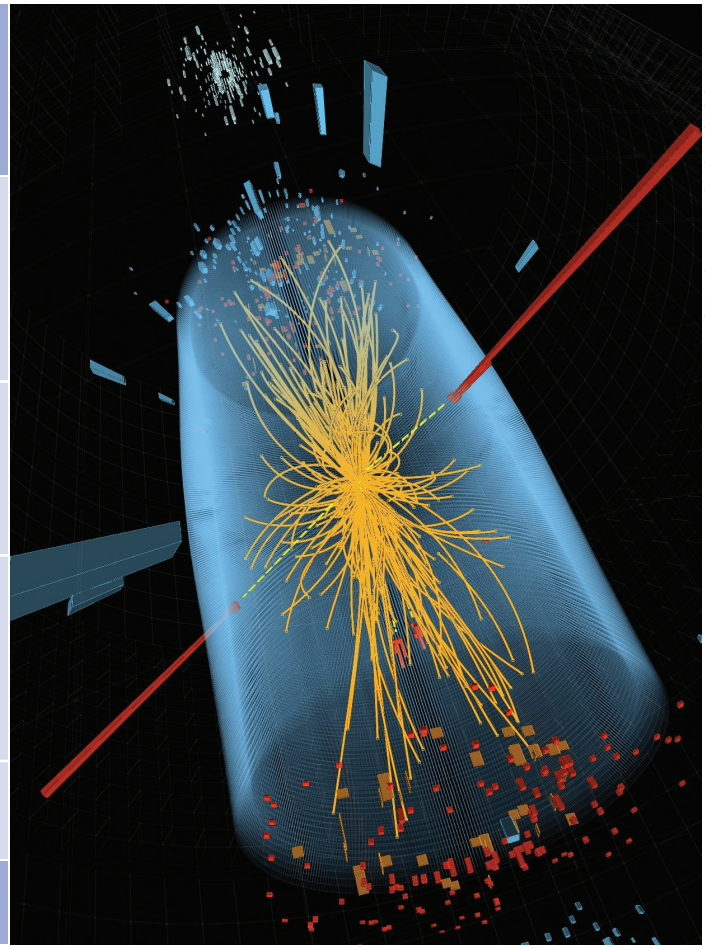

CERN, for the benefit of the CMS Collaboration

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Feedback

Letters to the editor can be sent to *Physics World*, Temple Circus, Temple Way, Bristol BS1 6HG, UK, or to **pwld@iop.org**. Please include your address and a telephone number. Letters should be no more than 500 words and may be edited. Comments on articles from *physicsworld.com* can be posted on the website; an edited selection appears here

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Proper perspective and nuclear power

In his review of *Powering the Future* by Robert Laughlin (July pp36–37), Paul Michael Grant states that environmental arguments against nuclear fission stem from a "lack of proper perspective". He continues: "It is instructive to point out that the death toll from a single commercial airline crash is approximately twice that of the confirmed number of radiation-exposure deaths from every nuclear-plant disaster to date, including Chernobyl and Fukushima."

In 2006 the Chernobyl Forum – an initiative of the International Atomic Energy Agency, in co-operation with the World Health Organization (WHO) and others – published a revised version of a report entitled *Chernobyl's Legacy*. In it, the authors draw on material from a related 2006 WHO report (*Health Effects of the Chernobyl Accident and Special Health Care Programmes*) to conclude that "Chernobyl-related radiation exposure… could mean eventually up to several thousand fatal cancers."

Three years later, a study by A Nesterenko *et al.* (2009 *Annals of the New York Academy of Sciences* **1181**), which incorporated around 1000 published research papers in evaluating the Chernobyl Forum report, suggested that "The Chernobyl catastrophe has already killed several hundred thousand human beings…The number of Chernobyl victims will continue to grow in the next several generations."

As for Fukushima, a recent worldwide study of Fukushima fallout (A Stohl *et al.* 2012 *Atmos. Chem. Phys.* **12** 2313) estimated that the emission of caesium-137 amounted to "about 43% of the estimated Chernobyl emission" and that 18% of the fallout was deposited over Japan, 1.9% on other land and the rest over the Pacific. In contrast, the Chernobyl fallout mainly fell on land. The number of radiation-exposure deaths eventually resulting from Fukushima may therefore amount to less than 10% of those from Chernobyl, since (18+1.9)% of 43% is 8.6%.

"Proper perspective" must take into account the foreseeable consequences of a disaster, not just its immediate effects. The 2006 and 2009 studies do so, and they suggest that an appropriate range for the "number of radiation-exposure deaths" resulting from "every nuclear-plant disaster to date" is between several thousand and several hundred thousand.

"Proper perspective" should also take into account wider effects on health and on the environment. On health, the 2006 report notes that "More than 4000 cases of thyroid cancer were diagnosed among those who were children and adolescents (0–18 years) at the time of the accident…it is most likely that a large fraction of thyroid cancers observed to date among those exposed in childhood are attributable to radiation exposure from the accident. It is expected that the increase in thyroid cancer incidence from Chernobyl will continue for many more years." On environment, it states that "In the Chernobyl Exclusion Zone and in certain limited areas some restrictions on land use will need to be retained for decades to come."

Brian Drummond
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Paul Grant (w2agz@w2agz.com) replies:
You are correct to point out the horrific enviro-ecological damage resulting from the Chernobyl accident, which is likely to persist well into the next century. However, the long-term biological consequences are less certain. Most attention has been given to the possible future emergence of thyroid cancer (a generally non-lethal and treatable affliction) in areas well outside the exclusion zone, where it is extremely difficult to ascertain a causal relationship by accepted statistical analyses. Contrast this uncertainty with the 3.5 million certified automotive deaths in the US since 1899 or the 500 accidental fatalities in the US (and more than 10 000 in less-developed countries) every year from household or workplace electrocution. Clearly, living within and enjoying the benefits of an industrialized society can be dangerous. We might consider returning to the safety of an agrarian, luddite-dominated culture – but didn't several dozen Europeans perish last year after consuming *E. coli*-infested "organically grown" bean sprouts?

Access for all

The news story "UK should lead on open access" (July p6) expresses a laudable aim, namely free access for all to research journals. As the article makes clear, this may take some time to achieve. In the meantime, however, there is a serious injustice being perpetrated against "external readers" at academic libraries, and this should be addressed as a matter of urgency. People in this category are currently denied access to issues of learned journals that are held electronically. In my own case, this ban exists in spite of the fact that I have been a regular subscriber to a university library since the 1970s and, moreover, a graduate of the institution. I have tried to get to the bottom of how such a situation was allowed to develop, and failed. Everyone to whom I have appealed – from library staff to government ministers – expresses sympathy and recognizes the problem, but all seem powerless to do anything about it.

So who has such an iron grip on the system that this unsatisfactory state of affairs continues?

Stuart Leadstone
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Editor's note:
The Finch report on open access, on which the news story was based, includes a recommendation that "major subscription-based publishers" should provide free "walk in" access at public libraries so that readers can access

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Feedback

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Other perspectives on nuclear power

In his reply to Brian Drummond's letter on "Proper perspective and nuclear power" (August p19), I am surprised that Paul Grant allowed Drummond's reference to the Nestorenko *et al.* publication (2009 *Annals New York Acad. Sciences* **1181**) to pass unchallenged. This document, with its claim that the Chernobyl accident has already killed several hundred thousand people (the figure of 985 000 is mentioned), was published without peer review and has since been disowned by the New York Academy of Sciences. As is well known, once a publication is on the Web, effective retraction is impossible; however, the academy states on its website: "The *Annals of the New York Academy of Sciences* volume "Chernobyl: Consequences of the Catastrophe for People and the Environment" ...does not present new, unpublished work, nor is it a work commissioned by the New York Academy of Sciences. The expressed views of the authors, or by advocacy groups or individuals with specific opinions about the *Annals* Chernobyl volume, are their own. Although the New York Academy of Sciences believes it has a responsibility to provide open forums for discussion of scientific questions, the Academy has no intent to influence legislation by providing such forums. The Academy is committed to publishing content deemed scientifically valid by the general scientific community, from whom the Academy carefully monitors feedback."

The World Health Organization report that Drummond also cited seems to be more credible, with an estimate of some thousands of deaths, including those directly exposed to radiation during the accident and subsequent clean-up operations. These are not negligible, but they also do not number in the "several hundred thousands". So much for a "proper perspective"!

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As someone who has several great-grandchildren to help focus my mind on the future, I agree with Grant's comments. Humans have been very fortunate in discovering fuel resources so far, and we have seen some dramatic solutions to various problems as science has progressed. However, there is strong opposition to oil drilling in some areas (for example) and I think that keeping our optimism in new ideas, and our fingers crossed, is not enough. A future serious conflict over supplies could result in the deaths of millions.

I was once a passenger in an old car that had a cable braking system that nearly caused it to swerve off the road during one hard stop. However, I do not judge modern or future motoring safety by that incident. Similarly, we have to move on with the best energy technology currently available to us, and nuclear power has changed since the days of Chernobyl.

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The open-access debate continues

As the managing editor of a firm that polishes the writing of researchers (especially those whose first language is not English) before they submit papers to learned journals, I have taken a keen interest in the debate about open-access publishing. As your article "UK to support open access" (August p8) described, the British government has recently endorsed the Finch report on open access, which concluded that publicly funded research should move to the "gold" or "author pays" model of open-access publishing. Under this system, researchers pay a four-figure sum to publish their papers in cheap-subscription journals that co-operate with Internet dissemination.

The historic purpose of academic journal publishers was twofold: to disseminate information by the distribution of hard copies, and to ensure quality control by the refereeing system. The first function is redundant now that we have the Web. Because researchers perform the second function themselves, it should be possible to reorganize so as to cut out academic journal publishers entirely. This would save a huge sum of money that could then be spent on research. Finch's assumption that we must choose between spending big money on subscriptions or publications is thus already out of date. The *arXiv* preprint repository will one day be seen as the start of a revolution, and the Finch report is a missed opportunity to organize the vanguard.

Currently, researchers have to typeset their own work, sign away their copyright to publishers and referee the work of their peers – all for no remuneration. They then pay large sums in publication fees or library subscriptions to buy that work back in refereed and collated form. The message we should send to journal publishers should be: "Thank you for your historic services, and goodbye".

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Steven Hall, managing director of IOP Publishing (which publishes *Physics World*), replies:
Garrett paints an extraordinarily simplistic and partial picture of scholarly publishing. The industry has successfully managed the transition from print to digital, and in doing so has massively expanded the dissemination of research to practically every researcher in need of access – all while reducing the time taken from submission to publication and continuing to provide a stamp of quality on every published article through the journal brand. To suggest that the need for journals ends with the death of print is absurd. Posting a manuscript in an online repository is not the same as publishing an article in a journal; that is why *arXiv* and physics journals co-exist.

Researchers do not perform peer review alone: publishers organize and manage it, invest heavily in people and systems to facilitate it, appoint and support editorial boards to oversee it and develop journals to meet the needs of scientific communities. Post-publication peer review simply has not worked.

Publishers also invest in so-called "metadata" services, such as seamless linking from one article to another, to make research more discoverable and accessible than ever before. By investing in new platforms for journal articles and other content, they make research more usable by enabling readers to extract figures, reuse data and access content via mobile devices. Do the critics of publishers think that this happens by magic – and cost-free magic at that? Finally, and contrary to Garrett's assertion, publishers continue to typeset articles and prepare XML from multiple formats submitted by authors. They edit them as well.

Of course, all these services could be provided differently, but they would still need to be provided and would still have their costs. The Finch report proposed a new way of meeting these costs while recognizing the critical role that formal publication plays in scholarly communications.