Paying for evaluating science

Abrol[1], in his note, raises obliquely, a fundamental issue of science policy which has long been neglected in the Western world. Who should pay for 'basic science' – that which is NOT connected in any way to societal values, or goods, such as 'sustainable development' or 'human welfare'? The latter was Nobel's stated goal for his prize winners! This metric is never even mentioned by the current Nobel selectors!

Alvin Weinberg, founding director of Oak Ridge National Laboratory, and I have separately addressed this question[2,3] in 1963 and 1985. Later I wrote a book with Shapley[4], the first major critique of the US Science Policy, and raised the same question in-depth. Who should pay for what science? And is the US science doing well at all, when cost-effectiveness is taken into account?

Let me start with another simple criticism of the simplistic use of citation data. In an era of computers and precision accounting, is it not absurd for citation champions to not normalize the number of papers and citations by dollars or yen or rupees spent by governments and industry, even adjusting for PPI. When this is done, the disparities become radically smaller.

Next, in that book, Shapley and Roy made the distinction between 'telestic', i.e. with goal or purpose and 'atelestic', with no special external purpose. This is the issue also raised obliquely by Abrol, and addressed cogently by Stokes[5], who develops further the Shapley and Roy theme. The question that many advocates of 'basic research', i.e. for science's sake alone, worry about is that such research will suffer if applications are stressed too much. Let us look at the data.

Admiral Paul Gaffney, former Head of the Office of Naval Research (ONR), stresses how this 'applications-driven basic research' was the ruling motif at ONR, which has been recognized by much of the US science community as the best agency for pioneering fundamental research[6]. Even more surprising to most younger policy makers is the fact that the same 'applications-driven' quality was the operative principle at Bell Labs, widely recognized as the most successful industrial laboratory ever. In academia since 1962, when I set up Penn State's Materials Research Labs (MRL), we have used the term 'applications-driven basic research' to describe what we do [following Bill Baker's (President of Bell Labs) advice in his speech on opening the lab]. In 2003, Penn State's MRL was rated #1 in the world by ISI, using most highly cited scientists' data.

'Applications-driven' as a national research and development (R&D) motif has a philosophical basis also. Upon his retirement, a former Vice-Chancellor of Melbourne University stated it best when discussing atelestic science: 'Science never made any country rich, rich countries (and I would add philanthropists) do science'.

My suggestions to analysts of Indian R&D policy include:

(i) Do not be over-bamboozled by Western-based and biased statistics on R&D output. Normalize everything, including those noted above and other obvious improvements such as, for instance, citation-inflation with time, as everyone does even for dollars spent. Pay special attention to the so called 'informal' citations identified first by Marx and Cardona[7–9] who show, for example, that Raman's main paper is under-cited by ISI by a factor of nearly 100.

(ii) Absolutely avoid Western science's 'fashionable' or 'cult' science – funding procedures. Most such, built under the magic (for the public) of euphoious terms, have ended as debacles: 'ceramic engines'; 'superconducting supercollider'; 'High T_c superconductors'; 'bucky balls'; 'nano-' anything.

(iii) Most assiduously, avoid the introduction of these passing fancies into science *education*. India has profited enormously by having B Sc and Ph D graduates solidly trained in the core sciences and engineering. Here our ideal good has been modified slightly to '*applications-connected* basic science' education. All students should, early on, be fully grounded in the fact that true science is rooted in reproducible data, facts – *not* theories.

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RUSTUM ROY

Evan Pugh Professor of the Solid State Emeritus,
The Pennsylvania State University,
102 MRL, University Park,
PA 16802, USA
e-mail: rroy@psu.edu

E-waste – A waste or a fortune?

With India facing an IT revolution, the country is starting to choke under a heap of electronic waste (e-waste) generated from obsolete computers and discarded electronic components. Frequent advances in technology require replacement rather than repair of older electronic devices. These throw-away electronics have created an e-waste crisis that is out of control and which has made management of this waste an environmental and health concern (Figure 1). The e-waste contains several hazardous and toxic materials like lead, mercury, cadmium, PVC plastics and brominated flame retardants, which are known to cause severe defects in the human body[1].

On an average when 1 tonne of e-waste is shredded and undergoes other separation steps during mechanical recycling, approximately 40 kg of dust-like material

Figure 1. Electronic waste generated from obsolete computers and discarded electronic components. Photograph downloaded from http://ewasteguide.info/methodology_1.

is generated having precious metals, which are otherwise toxic if they exist in nature in such high concentration[2]. It clearly shows that a hidden treasure lies beneath this huge ever-growing mountain of e-waste. If metals are extracted properly from e-waste, this will create a new business opportunity of recycling. Till now, few companies have realized the potential of this booming business. Investments in this new sector will lead to a win–win situation for both the company as well as the country. Moreover, the land which is being wasted as landfills or dumping sites for e-waste can be put to more productive use like agriculture, infrastructural development, etc.

However, financial constraints, ignorance and unwillingness are the biggest hurdles in the way of safe recycling of e-waste. However, stringent environmental regulations along with government support to establish recycling facilities to manage e-waste can give us a better model. At present, e-waste recycling is largely going on in Delhi, Meerut, Bangalore, Mumbai, Chennai and Ferozabad. The procedure of metal extraction includes manual sorting, magnetic separation, reverse osmosis, electrolysis, condensation, electrolytic recovery, filtration and centrifugation[1]. But these methods are less efficient and harmful to both the environment and human health. The biohydrometallurgical techniques provide us with a better solution, i.e. to apply a bacterial leaching process ('bioleaching') for mobilization of metals from the fine-grained e-waste. Bacteria and fungi (*Bacillus* sp., *Saccharomyces cerevisiae*, *Yarrowia lipolytica*) have already been used to mobilize Pb, Cu and Sn from printed circuit boards[3]. At electronic scrap concentration of 5–10 g/l in the medium, *Thiobacillus thiooxidans* and *Thiobacillus ferrooxidans* were able to leach more than 90% of the available Cu, Zn, Ni and Al. *Aspergillus niger* and *Penicillium simplicissimum* were able to mobilize Cu and Sn by 65% and Al, Ni, Pb, Zn by more than 95% at a scrap concentration of 100 g/l in the medium[2]. Leached and recovered metals might be recycled and reused as raw materials by metal manufacturing industries. This method has the potential to reduce waste disposal and raw material costs, and also provide income from e-waste.

Using biological techniques, recovery efficiency can be increased, where physico-chemical and thermal methods alone are less successful. Extended producer responsibility[4] to recycle e-waste will soon become a financial and material necessity, if we are to continue with our current standard of living.

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VIDHI GUPTA
PARUL LAUL
SUDHIR SYAL*

Department of Biotechnology and Bioinformatics,
Jaypee University of Information Technology,
Waknaghat,
Solan 173 215, India
**e-mail: sudhirsyal@rediffmail.com*

Energy saving and the Indian Standard Time

Ahuja *et al.*[1] have suggested that advancing the Indian Standard Time (IST) by half an hour would significantly save energy for our country. Their argument essentially implies that energy could be saved by making full use of daylight in the workplace, thus avoiding the usual electrical lights. The desired objective can also be fulfilled equally well, if instead of advancing the time, we start the office/business activity a little earlier. In either case, people would indeed be required to make some sort of adjustments to get adapted to the new scheme of things. The latter option in fact offers more flexibility and thus is better. To appreciate this, one has to note that there does not necessarily exist any uniformity in the working hours of different organizations. For example, hospitals start working typically by 8 a.m., whereas government offices start at 9 or 10 a.m. Many schools start early in the morning, typically between 7 and 8 a.m. Uniformity in timings is not necessary and therefore different working hours can be chosen in different parts of the country, depending on the