

savings. Similar savings in the residential sector can be obtained by simple improvements such as sealing leaks, setting thermostats back at night, and using compact fluorescent lights that pay for themselves in less than a year. New construction, especially in developing countries, is particularly important in meeting future global climate goals. China, for example, is constructing approximately 10 million new residential units per year. The new buildings can be made twice as energy efficient as existing ones with little or no cost increase.

Possible environmental impacts of any new energy sources must also be considered. Covering many buildings in an urban area with photovoltaic systems will, for instance, have the negative consequence of enhancing heat-island effects. And a few studies suggest that large-scale wind farms would create "nonnegligible climatic change at continental scales"¹ or would affect local meteorology.² It is clear that further study is needed to determine the severity of any long-term effects.

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Evaluation by citation: An imperfect system

Bibliometric measures such as impact factor, citation rate, and *h*-index are gaining influence on the funding of research units and the hiring and promotion of individual scientists. Strengths and weaknesses of such a system are being widely discussed. However, appropriate evaluation of research and researchers requires a reliable and complete bibliographic database.

Currently, most bibliometric evaluations are based on the source index of the ISI Web of Knowledge, which has a user-friendly basic search option that delivers publication information, citation rates, and *h*-indices within seconds. Almost anyone can retrieve information within minutes, so evaluation based on the source index seemingly requires no special knowledge.

Weaknesses of the system become evident when one goes to the cited-reference search. That database contains many more bibliographic data, including citations to papers published in journals not included in the source index; to books and conference proceedings not in the source index; and, most important, to papers cited with numerous typographical errors or in an unofficial bibliographic style.

We wanted to check whether the data inconsistencies between the two databases would be distributed randomly and thus not affect relative trends. We chose a prominent example: Danish physicist Jens Lindhard (1922–97), a Nobel Prize nominee well known for contributions to condensed-matter physics, ion–solid interactions, and other areas.

The basic source-index search shows 3735 citations as of 13 January 2009 and an *h*-index of 14 for Lindhard—a nice

achievement if he were a postdoc in physics. However, the cited reference search shows more than 10 000 citations and an *h*-index of roughly 25, an appropriate number for a professor. Lindhard published 49 items total, not all of which are expected to generate citations, so his *h*-index would never be much higher.

The table shows four of Lindhard's highly cited papers. The first paper provided the theoretical basis for the entire field of ion implantation, a key technique in microelectronics. The citation total of 4008 indicates top impact, and the paper has rightly been named a citation classic. Yet the paper does not even appear in the source index! The second paper shows that such omission is not general for articles in that journal. The third, the central paper in the physics of channeling, a phenomenon in the interaction of swift particles with crystals, is still highly cited every year, yet of more than 1800 citations, only 19 are mentioned in the source index.

A particularly spectacular case is the fourth paper, another classic. Both the source and citation indexes show 4 citations when one searches using Lindhard's name. Under Niels Bohr, the first author, the source index likewise shows 4 citations, but the citation index has 1615. We have no way of understanding the discrepancy or evaluating its significance. Citation counts of Nobel laureates were studied with special care in the beginnings of bibliometry, to support the postulate that high citation rate indicates high research quality.

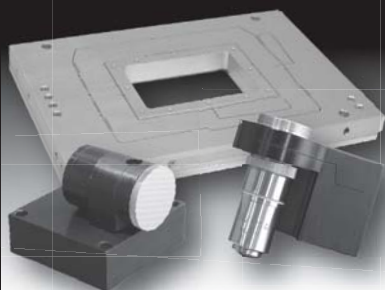
One could argue that Bohr and Lindhard are no longer alive and, therefore, no longer subject to research evaluation. We looked at similar data for one of us (Sigmund). The source index delivers an *h*-index of 46, yet 11 highly cited papers are not mentioned at all, including a paper with 1025 citations.

Our observations confirm the repeated claim of Eugene Garfield, founder of the Science Citation Index, that citation analysis with the aim of evaluating researchers or research groups should only be performed with a complete list of publications at hand. Our examples show that despite significant development of the two data-

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Sample references

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Paper	Basic search (source index)	Cited reference search (citation index)
1	0	4008
2	1584	1890
3	19	1845
4	4 (4)	4 (1615)

bases, Garfield's statement is still valid.

We conclude that the source index, accessed through the basic search function, cannot be used uncritically in research evaluation. The citation index contains most of the pertinent information, but it is not user friendly. And a fundamental weakness is that it underestimates the citations to journals not included in the source index.

A valid citation analysis is time consuming; it requires insight and, therefore, needs to be performed by experts.

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One thing Wheeler didn't do

One thing lacking in the special issue dedicated to John Wheeler (PHYSICS TODAY, April 2009) is any comment on why he did not receive the Nobel Prize. I think the explanation is political: Wheeler was a supporter of the Vietnam War. In 1967, while working on my thesis at Princeton University, I was stunned when Wheeler began one of our morning meetings by gleefully telling me that he had spent a good part of the night slinking about campus with a spray can to paint pro-war messages over peace symbols and other antiwar graffiti. I had the impression that he wanted credit for his act of civil disobedience and that he was hoping for repercussions. At the time I did not know how to react to that escapade, but I now think that Wheeler may have had a point—the Vietnam War certainly provided plenty of blame to share among all the participants.

The Swedish government fervently opposed the war, so much so that the prime minister denounced the bombings of Hanoi as crimes comparable to those of Guernica, Oradour, Babi Yar, Katyn, Lidice, Sharpeville, and Treblinka. It is easy to imagine that this stance put considerable pressure on the Nobel Committee not to award the prize to Wheeler. Political influence has often played a role in the literature prizes—not to mention the peace prizes, for which political influence is the name of the game. Political influence in the physics prizes is less obvious, but we can occasionally see a hint of it in the adroit splitting of the prize among several nationalities.

Wheeler has been described as the cleverest physicist of his generation not to receive a Nobel Prize. I recall the dis-

appointment that I felt in the 1970s and 1980s when his name failed to appear in the annual announcements. Of course, Wheeler was probably too much of a gentleman to entertain such thoughts, but I can't help suspecting political motivations.

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On Wheeler and fission

John Wheeler's 1967 article on the mechanism of fission, which was recently reprinted (PHYSICS TODAY, April 2009, page 35), provided insight into the history of that exciting time that could only be related by one who was there. However, two aspects of that history tend to get overlooked. First, the liquid-drop model of the nucleus was conceived not by Niels Bohr but by George Gamow in late 1928 just before he left Copenhagen for a visit to Cambridge;¹ he briefly described it in early 1929 in a discussion, held at the Royal Society in London, that was opened by Ernest Rutherford.² Second, the perturbation coefficients Bohr and Wheeler used for investigating the question of the fission barrier were different from those defined in their paper, and their equation for the configuration energy contains a misprint.³ Wheeler's fellow postdoc in Copenhagen, Milton Plesset, gave a detailed analysis of the Bohr and Wheeler calculation⁴ (which they characterized as "straightforward"!); I have prepared an upper-undergraduate-level treatment of the calculation.⁵

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Correction

September 2009, page 42—The neutron interferometry experiments on the Aharonov–Bohm duals were performed at the University of Missouri, not the University of Melbourne. They were a team effort led by Tony Klein and Sam Werner, with researchers from Melbourne and Missouri. ■

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