LA-UR-16-23445
Approved for public release; distribution is unlimited.

Title: Using the H Index to Assess Impact of DOE National Laboratories

Author(s): Springer, Everett P.

Intended for: Report

Issued: 2016-05-13

Using the H Index to Assess Impact of DOE National Laboratories

Everett P. Springer
Science Resource Office Communications and Peer Review

May 2016

Introduction

Impact of science, technology, and engineering (STE) is a key measure of research performance for government-funded scientific organizations. National research evaluation efforts such as the Research Excellence Framework in the United Kingdom and Excellence in Research for Australia have attempted to examine research impact to provide a basis for funding. The U. S. National Science Foundation is requiring a broader impacts criterion statement on proposals submitted for funding and this statement is a criteria used to determine funding. The October 2013 issue of Nature (Nature Publishing Group 2013) dealt with research impact from different perspectives. Understanding and measuring research impact is here to stay.

Still, impact has many forms. Harzing (2014) provided some guidelines for an individual researcher to address impacts of their research. Harzing referenced the Emerald Impact Matrix (The Emerald Impact Matrix can be found at http://www.bl.uk/reshelp/bldept/socsci/events/abs/johnpeters.pdf by Peters (2010)) and noted that the nonacademic measures are difficult measure meaning that academic measures such as citations will remain the primary mechanism for impact assess for now. The Emerald Impact Matrix identified six impact zones. These are:

Knowledge – scholarship, which contributes to the body of knowledge and generates further research. Assessed by: citations, usage statistics, peer recognition, self-stated research conclusions.

Teaching and learning – students and faculty are direct consumers of research. Assessed by: clarity of conclusions to aid learning, provision of case studies and teaching examples, usage statistics, course adoption/curricula change.

Practice – business leaders, practitioners and consultants in both private and public sector organizations are all affected by the outcomes of research. Assessed by: university-business collaboration, consultancy application, implications for practice self-stated.

Public policy – State officials, politicians, decision makers in public bodies, institutions and charities draw on research to shape their policies. Assessed by: self-stated potential implications, subsequent policy revisions.

Society and environment – includes impact on the environment, the ability to influence social responsibility in industry, business and public policy and the incorporation of social and environmental values in research outputs. Assessed by: informing social policy, industry adoption, implications for society self-stated.

Economy – research which contributes to organization-level or macro-level wealth creation and business advancement. Assessed by: future economic savings, revenue increase, self-assessed business/economic impact.

These six elements of the Emerald Matrix do provide a broad array of measures for the impact of STE, and the DOE National Laboratories clearly contribute in each of these elements. Impacts in general are evaluated post research project environment because it is so difficult to assess impacts *apriori*.

The most readily accessible elements of the Emerald Matrix by quantitative measures are the knowledge and economy related measures. In this paper, the H Index for an institution will be used to assess STE impact, which is in the knowledge generation element. The H Index was developed by Hirsch (2005) as a measure of an individual's scientific impact. The H Index is defined as the number of publications that have been cited h or more times for a given author. It has been generalized to organizations. Doing so leads to a complication in that H index scales with the number of publications. Although this may not be problematic when comparing individual researchers, it systematically favors larger institutions. Molinari and Molinari (2008) proposed an alternative index (hm) designed to assess organizational impact. It transforms the H Index for an organization into an impact index by removing a factor dependent on the number of publications. The hm provides another approach to compare institutions provided that differences in the citation patterns associated with fields of study are addressed. Kinney (2007) used the Molinari and Molinari (2008) approach to compare various scientific institutions in nonbiomedical research areas. Kinney (2007) used the Thomson Reuters Web of Science (WoS) as the source and used publications in nonbiomedical research areas, which is very important because the research areas of universities are much broader than say a DOE national laboratory. Also there are differences in citation rates for the various research fields that make comparisons between individuals or organizations difficult. The results from Kinney (2007) are given in Table 1 and indicate that the DOE national laboratories compare favorably with the selected universities in terms of impact (hm) in the research areas used in Kinney's analysis.

This report will compare hm for DOE national laboratories using an approach similar to Kinney (2007) providing a measure of impact of the DOE national laboratories.

Table 1. Results of Kinney (2007) H Index impact analysis. Sorted on hm.

Organization	Number of publications	H index	hm
Harvard	11,165	256	6.15
SLAC	1,418	103	5.65
Fermi	1,304	93	5.28
Johns Hopkins	5,959	167	5.16
Princeton	9,084	197	5.14
Columbia	7,028	174	5.03
Chicago	6,354	167	5.03
Brookhaven	7,809	179	4.96
Caltech	13,381	217	4.85
LLNL	10,605	196	4.81
Stanford	13,215	213	4.79
Duke	3,724	123	4.74
LBNL	8,900	179	4.71
MIT	19,542	241	4.63
Northwestern, Evanston, IL	6,801	144	4.22
UC Berkeley	19,963	220	4.19
Indiana, Bloomington, IN	4,518	118	4.07
Minnesota, Minneapolis/St. Paul, MN	9,370	158	4.05
Argonne	9,413	156	4.01
Los Alamos	11,776	163	3.83
Wisconsin, Madison, WI	10,647	156	3.81
Michigan State, East Lansing, MI	4,894	114	3.81
Michigan, Ann Arbor, MI	10,657	150	3.67
Iowa, Iowa City, IA	3,604	95	3.59
Purdue, West Lafayette, IN	10,582	141	3.46
Pennsylvania State, University Park, PA	10,170	138	3.44
Oak Ridge	10,266	138	3.43
Ohio State, Columbus, OH	8,230	126	3.42

Methods

Data

Data for each DOE national laboratory was obtained from the WoS InCites tool for the period 1990 – 2008. More recent data were not collected because citations would not have had an adequate time to accumulate. All data were searched and downloaded from InCites on April 12, 2016. Data were collected included the total WoS documents and the H index for each laboratory. Data were obtained on a two-year interval over the 1990-2008 period. No screening of the documents for research consistency of the type performed by Kinney (2007) occurred, which reflects the assumption that the DOE national laboratories work in the same general research areas, eliminating the need to for efforts aimed at comparing diverse organizations including universities, DOE national laboratories, and other government research organizations.

For purposes of comparisons at the research area level, data were also collected over the same time intervals and on the same date for the following Essential Science Indicator fields, chemistry, engineering, and physics to compare at a research area level.

Calculation of hm

The hm impact was calculated using the relationship from Molinari and Molinari (2008) (also used by Kinney (2007))

hm = H Index/(Number of publications)**0.4 (1)

where: H Index is the InCites provided H Index value, and number of publications is the InCites provided WoS Documents. Kinney (2007) suggested a 200-paper minimum for the calculation of hm, but I used 500 to provide a sufficient sample size.

Results

InCites data

For the InCites, only the DOE national laboratories were compared. Table 2 provides the same information as in Table 1 for the laboratories at 2008 for the All Fields (i.e. all research fields) InCites data. The reason for the 2008 cutoff is the effect of the recent period on citations and the H Index. From Table 2, the overall higher values for H Index and hm for the DOE national laboratories over those in Table 1 are substantial. The H Index for Los Alamos more than doubled from 163 to 348 over this period. This increase is partially due to the increase in citations over this period as opposed to the 1980 – 1998 period used by Kinney, and the development of the internet, which has made finding and accessing publications much easier than prior to the advent of the internet. Similar to the Kinney results (Table 1), both Stanford Linear Accelerator (SLAC) and Fermi National Accelerator Laboratory (FNAL) have the highest hm values. The multiprogram laboratories are lead by Lawrence Berkeley (LBNL), Brookhaven (BNL), Los Alamos (LANL), Lawrence Livermore (LLNL), Argonne (ANL), Pacific Northwest (PNNL), Oak Ridge (ORNL), and Sandia National Laboratories (SNL). It is reasonable to assume that given the increase in the DOE national laboratories hm values in Table 2 that the universities in Table 1 would see a similar increase in their hm values for this period for the same reasons.

The trends in hm are presented for the multiprogram laboratories only in Figure 1 for the All Fields data. The hm values start higher than the values from Kinney (2007) indicating that there may be a data difference. There was work at the DOE national laboratories on the human genome and other biomedical related projects, which would have been excluded in Kinney's analysis. The inclusion of this work may have pushed the hm index higher. From Figure 1, the trends appear to be upward for all laboratories except LLNL for the 1990 – 2002 period. All DOE national laboratories exhibit a downward trend after 2004 except LBNL, which continued upward. A possible explanation for the downward trend was the fact that more recent publications have not had the time necessary to accumulate citations. If this was the case, then it would have been expected to affect LBNL too, but as noted, the LBNL trend was upward. The reason for the downward trend is not apparent, and more investigation is needed to understand its cause.

The results in Table 2 are not directly comparable to the DOE national laboratory results presented in Table 1. As described earlier, Kinney (2007) used a much different approach to obtain his WoS data. There is overlap in time periods used by Kinney (1980 – 1998) and in this study (1990-2008), but data collection differences make any direct comparisons of hm between this study and Kinney (2007) dubious.

The Essential Science Indicators (ESI) research area fields were used to further investigate impact. The ESI fields classify research at the journal level so all articles in a given journal will be classified in the same way, so, for example, an article about materials may be classified as physics. Also, major journals such as Science and Nature are classed as multidisciplinary. Still, the restriction provided by the ESI scheme could allow a better institutional comparison. As a first test, Table 3 provides the hm rankings for the ESI physics category for the 1990-2008 sampling period. Physics is a major research area for DOE national laboratories so a large change in ranking from the All Fields was not expected and did not occur. The most dramatic difference is the rise of PNNL in this ranking. Figure 2 provides the hm trend over the sampling period for the physics data, and the rise of PNNL from the bottom in 1990 to the top in 1994 is interesting. Patterns observed in the all fields analysis, which are also prevalent in the physics data, include the overall decline starting in 2004 and the immunity of LBNL to this trend.

Table 2. Comparison of DOE national laboratories in 2008 based on InCites data for All Fields. These data represent the 2008 sampling data from the 1990 – 2008 sampling period.

Facility	Number of WoS Documents	H Index	hm
SLAC	5177	212	6.93
FNAL	4933	208	6.93
NREL	3933	186	6.79
LBNL	29086	409	6.70
BNL	15856	291	6.08
TJNAL	1497	104	5.58
LANL	30846	348	5.57
LLNL	19860	287	5.48
ANL	20725	280	5.25
PNNL	11280	218	5.22
Ames Laboratory	6373	166	4.99
ORNL	24331	278	4.89
SNL	14443	215	4.66
NETL	1401	82	4.52
PPPL	2976	97	3.96
INL	2702	78	3.31

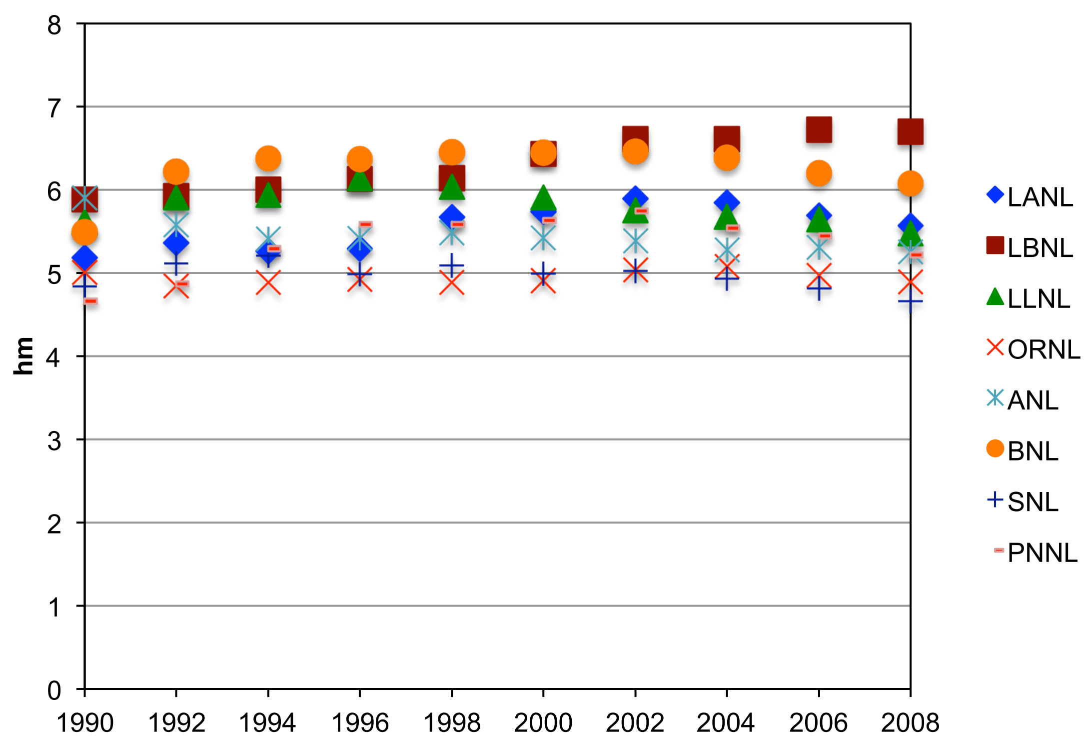

Figure 1. The hm values for the All Fields research area plotted over time for the multiprogram DOE national laboratories from the 1990 – 2008 period.

Table 3. Comparison of DOE national laboratories in 2008 based on InCites data for ESI physics research field. These data represent the 2008 sampling data from the 1990 – 2008 sampling period.

Facility	Number of WoS Documents	H Index	hm
SLAC	3619	189	7.13
NREL	1461	130	7.05
PNNL	1649	129	6.66
LBNL	12645	282	6.45
BNL	8401	232	6.25
FNAL	4195	171	6.08
LANL	13688	265	5.87
TJNAL	1387	104	5.76
Ames Laboratory	3254	146	5.75
ANL	10264	225	5.59
LLNL	7863	202	5.59
SNL	4819	163	5.48
ORNL	8532	195	5.22
NETL	116	31	4.63
PPPL	1926	91	4.42
INL	497	50	4.17

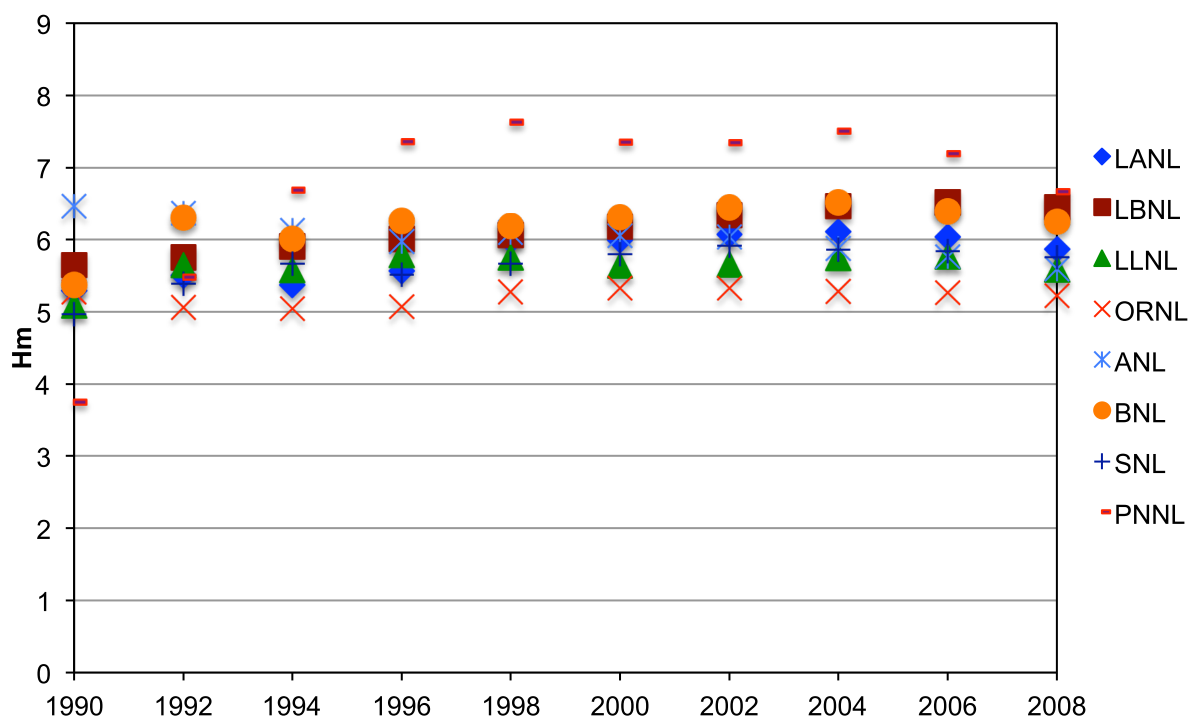

Figure 2. The hm values for the physics ESI research area plotted over time for the multiprogram DOE national laboratories from the 1990 – 2008 period.

Table 4. Comparison of DOE national laboratories in 2008 based on InCites data for ESI chemistry research field. These data represent the 2008 sampling data from the 1990 – 2008 sampling period.

Facility	Number of WoS Documents	H Index	hm
LBNL	5581	186	5.90
ORNL	4884	143	4.78
PNNL	4052	140	5.05
LANL	4846	140	4.70
ANL	4084	131	4.71
SNL	3245	123	4.85
BNL	2708	122	5.17
Ames Laboratory	2004	98	4.68
LLNL	2670	100	4.26
NREL	880	92	6.11
SLAC	546	70	5.63
NETL	634	63	4.77
INL	590	35	2.73
PPPL	385	32	2.96
FNAL	33	8	1.98
JNAL	20	8	2.41

The ESI chemistry area was the next area that is examined and results are provided in Table 4 for the data from 2008. The number of WoS documents is generally lower than for the physics area. Again, LBNL is the lead for the multiprogram laboratories, and PNNL and BNL are also in the upper tier. The trend in hm over time for the chemistry area is presented in Figure 3. Only LANL and LBNL are represented in 1992 because the other laboratories did not have the 500-document minimum that I applied to these data. In 1994, all of the laboratories except LLNL and PNNL were present. In 1996 all laboratories have achieved the 500-document limit and are present. There appears to be a peak in 2000 with a decline in hm that follows. The distribution is tighter in 2008 than previous years.

Figure 3. The hm values for the chemistry ESI research area plotted over time for the multiprogram DOE national laboratories from the 1990 – 2008 period.

The final ESI research area studied was engineering. Results are given in Table 5 and Figure 4. The most immediate observation from Table 5 is that the number of WoS documents is substantially reduced over the other research areas, and many DOE national laboratories do not reach the 500-document limit. The trends over time indicate that SNL and LBNL are leading for the DOE laboratories. SNL is not surprising given its engineering focus. Again, all DOE national laboratories except LBNL appear to exhibit a declining trend after 2002.

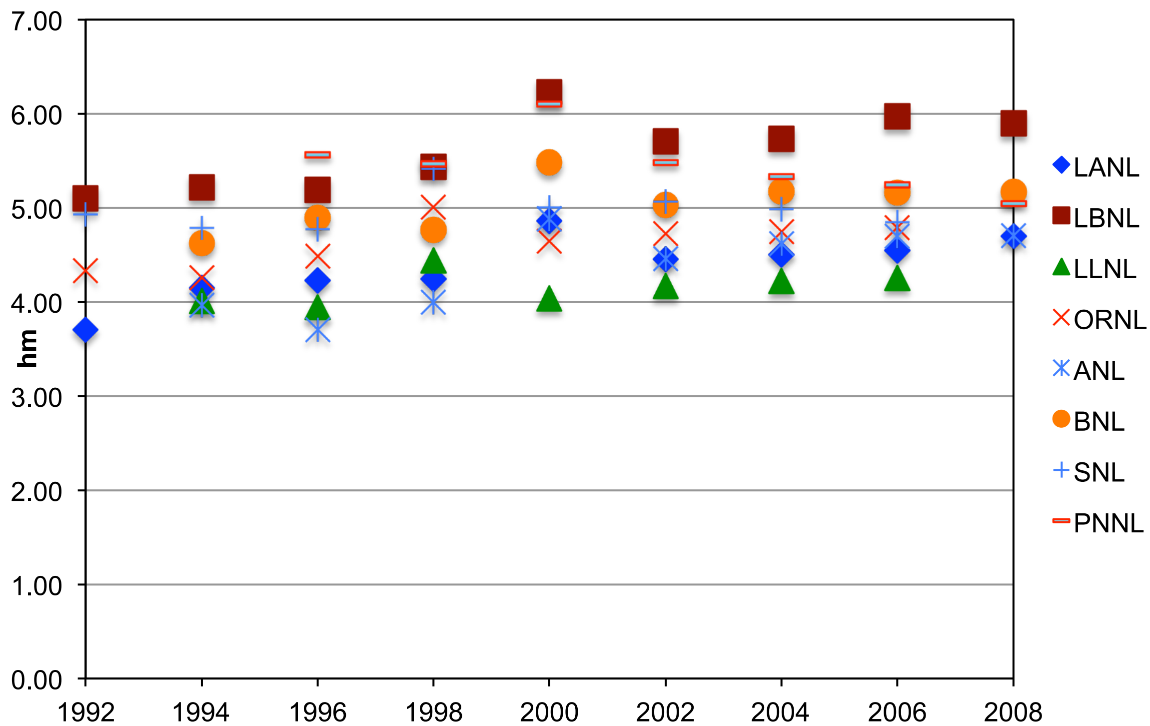

Figure 3. The hm values for the chemistry ESI research area plotted over time for the multiprogram DOE national laboratories from the 1990 – 2008 period.

Table 5. Comparison of DOE national laboratories in 2008 based on InCites data for ESI engineering research field. These data represent the 2008 sampling data from the 1990 – 2008 sampling period.

Facility	Number of WoS Documents	H Index	hm
NREL	534	74	6.00
LBNL	1097	79	4.80
NETL	317	47	4.70
SNL	2856	108	4.48
PNNL	926	66	4.29
LLNL	1698	80	4.08
ANL	1629	78	4.05
ORNL	2340	90	4.04
LANL	1937	77	3.73
Ames Laboratory	89	21	3.49
BNL	344	31	3.00
INL	813	43	2.95
FNAL	27	10	2.68
SLAC	46	12	2.59
PPPL	504	31	2.57
JNAL	10	4	1.59

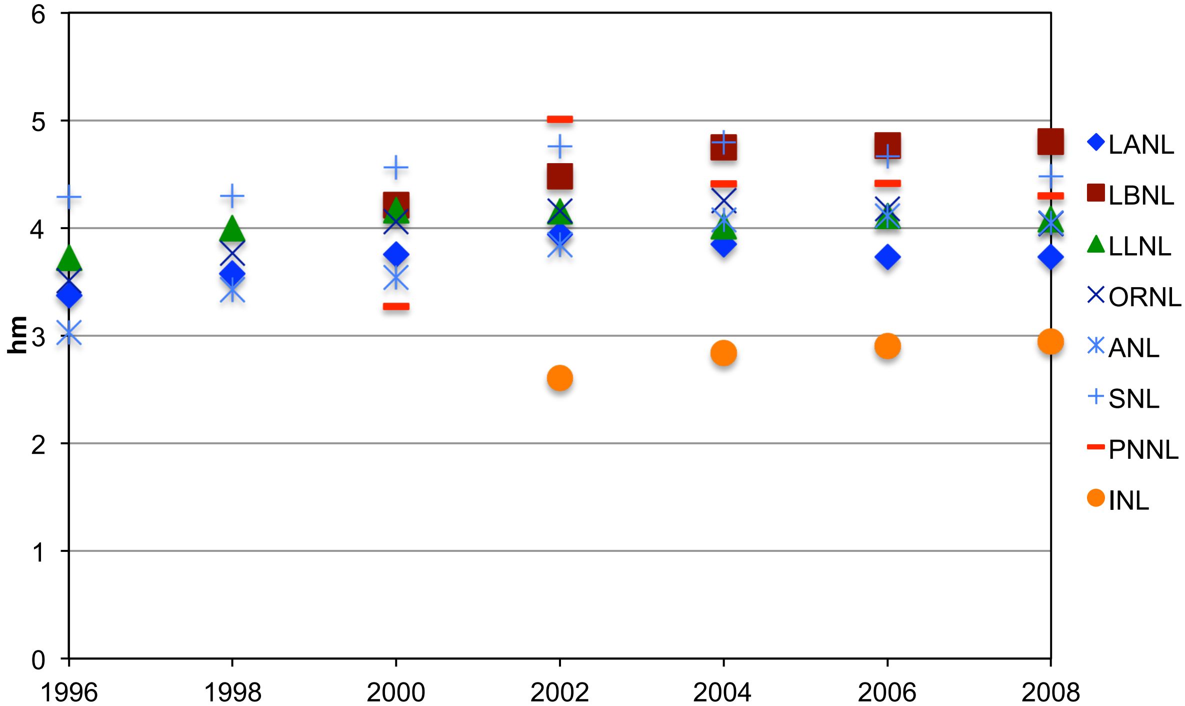

Figure 4. The hm values for the engineering ESI research area plotted over time for the multiprogram DOE national laboratories from the 1990 – 2008 period.

A comparison using InCites physics

The comparison between universities and government laboratories performed by Kinney (2007) was quite revealing in terms of how the DOE national laboratories compared in nonbiomedical areas. Using the physics ESI category from InCites, data were collected for top U.S, institutions on April 27, 2016. Results using the same hm calculation for selected institutions are presented in Table 6.

The immediate feature from Table 6 is the high impact, based on hm, for two corporations, IBM and AT&T indicating the cutting edge research generated by these companies. There are a number of universities, Harvard, Stanford, UC Santa Barbara, MIT, CalTech, etc. at the top of the list. Still, the DOE national laboratories are present and represent solid rankings for the physics category. These results are consistent with Kinney (2007) and indicate that at least in the physics area the impact of the DOE laboratories on physics research is important.

Table 6. Comparison of U. S. research organizations for 2008 using the data from the InCites ESI physics area. These data represent the 2008 sampling data from the 1990 – 2008 sampling period. Data collect April 27, 2016.

Name	Web of Science Documents	h-index	hm
International Business Machines (IBM)	9068	288	7.52
AT&T	7895	272	7.51
Stanford Linear Accelerator Center	4079	189	6.80
Harvard University	13780	296	6.54
National Renewable Energy Laboratory	2123	140	6.54
Stanford University	15629	308	6.47
University of California Santa Barbara	12808	283	6.44
Massachusetts Institute of Technology	23156	339	6.09
California Institute of Technology	13380	271	6.06
University of Washington Seattle	8544	224	5.99
Princeton University	15497	282	5.94
Cornell University	9673	230	5.85
Lawrence Berkeley National Laboratory	19273	300	5.80
University of California Berkeley	22869	320	5.77
University of California Santa Cruz	3653	152	5.71
Pacific Northwest National Laboratory	2803	136	5.68
National Institute of Standards & Technology	11778	240	5.65
New Mexico State University	1110	92	5.57
Fermi National Accelerator Laboratory	6443	184	5.51
Brookhaven National Laboratory	12899	242	5.49
University of California Riverside	4590	158	5.42
University of California Los Angeles	11498	227	5.39

Ames National Laboratory	4511	152	5.25
University of New Mexico	4565	152	5.22
Los Alamos National Laboratory	18848	267	5.20
Naval Research Laboratory	9041	199	5.20
University of California San Diego	11294	214	5.12
University of Illinois Urbana-Champaign	13752	231	5.11
University of Chicago	26226	299	5.11
Lawrence Livermore National Laboratory	11471	214	5.09
University of California Irvine	6016	165	5.08
Jefferson National Accelerator	2212	108	4.96
Argonne National Laboratory	15732	235	4.92
Sandia National Laboratories	6804	166	4.86
University of Michigan	12007	206	4.81
Jet Propulsion Laboratory	2671	112	4.77
University of Maryland College Park	14755	221	4.75
University of Tennessee Knoxville	6894	162	4.72
University of California Davis	6902	159	4.63
Texas A&M University College Station	8607	171	4.56
Oak Ridge National Laboratory	12938	201	4.55
University of Wisconsin Madison	11510	191	4.54
National Energy Technology Laboratory	265	36	3.86
Princeton Physics Laboratory	3064	92	3.71
Idaho National Laboratory	702	51	3.71
New Mexico Institute	185	27	3.35

of Mining Technology			
University of California Merced	365	28	2.64

Summary and Conclusions

An analysis using the modification of the h index proposed by Molinari and Molinari (2008) to account for impact and the number of papers was performed for the DOE national laboratories using data obtained from the Thomson Reuters InCites tool for the 1990 – 2008 time period. Analyses were performed for the DOE laboratories for the all fields and the physics, chemistry, and engineering ESI research areas.

Results indicated that there was a general increase for all DOE laboratories in hm for the period 1900 – 2000. After that, almost all of the laboratories exhibited a declining trend except LBNL. The DOE laboratories shifted ranking position between ESI research areas, which were expected because of the different primary missions of these laboratories. For instance, in engineering SNL had a higher impact than either LANL or LLNL, which is not unexpected because of SNL's engineering role in the weapons program.

A final comparison of hm for selected U.S organization in the ESI physics category indicated that the DOE national laboratories play an important role in the physics research of the U.S.

The approach and analyses performed for this report provide an alternate approach to assess research impact through knowledge generation. The InCites tool does provide a quicker and perhaps more consistent method to derive data for these analyses particularly when focus is on a particular subject area than the approach of search the WoS database for documents and culling those that are not relevant.

We must remember that this analysis, like any based on citation data, is only one-way of assessing knowledge generation. Moreover, knowledge generation is only one of multiple types of impact produced by scientific research. The impact of the DOE national laboratories can take many other forms, such as the others listed in the Emerald Impact terms. The goal of assessing the impact of the laboratories will be greatly served by efforts to embed assessments of knowledge generation, such as those presented here, within a broader landscape of impact analyses.

Acknowledgement

Special thank you to Amy Guthormsen for her review and comments, which significantly improved this report.

References

Harzing, A.W. 2014. From publication to impact (slides) - 30 minute presentation (courtesy of Middlesex University, http://www.harzing.com/download/pubtoimpact.pdf)

Hirsch, J. E. 2005 An index to quantify an individual's scientific research output. Proc. Natl Acad Sci, 102(46):16569--16572.

Kinney, A.L. 2007. National scientific facilities and their science impact on nonbiomedical research. Proc. Natl Acad Sci, 104(46):17943-17947.

Molinari, A. and J-F. Molinari. 2008. Mathematical aspects of a new criterion for ranking scientific institutions based on the h-index. Scientometrics 75 (2):339-356.

Nature Publishing Group. 2013. Research evaluation: Impact. Nature. 502:287.