December 2012

Advantage Business Media

2013 Global
R&D Funding Forecast

- Global R&D Increases 1.8% to $1.496 Trillion
- U.S. R&D Declines Again in Real Dollars
- Globalization Shifting Industrial Investments
- U.S. R&D Enterprise Accounts for 8.3 Million Jobs

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2013 Global R&D Forecast:
CEO Message

Battelle and *R&D Magazine* are honored to present our latest forecast of global research and development funding and related trends, including the annual survey of researchers, which gives us insight into their challenges, issues and opportunities.

For the first time, global R&D spending has grown more than $50 billion over the past year, totaling $1.5 trillion. In sectors like energy, we see important market transformations enabled by past R&D that now influence the outlook for research in 2013. Common technology themes, such as “big data” analytics, are impacting multiple sectors, while the need for greater cost efficiency is a significant driver in healthcare and defense.

There are other interesting trends, some near and dear to Battelle, such as the education of future scientists and engineers. The trend of more technologists being created in the BRIC countries than in the United States and Europe continues. It is one reason that Battelle continues to emphasize the importance of investing in Science, Technology, Engineering and Mathematics (STEM) education initiatives.

As I write this letter, the United States is at the very edge of the so-called “fiscal cliff.” The team of analysts who prepared this forecast made the assumption that some level of compromise will be reached by January 2, 2013, or that the automatic spending cuts mandated by the Budget Control Act will be delayed. And the United States is not alone when it comes to fiscal issues. A solution to the debt crisis in Europe continues to be evasive and economic growth across Asia has slowed. Such economic uncertainty affects the outlook for R&D funding, but we believe that the findings in this report will remain relevant as the world makes investment decisions for the long term.

I hope that this report leaves you with a better understanding of where the world’s R&D investment is making an impact today and well into the future. Your thoughts are always welcome.

Jeffrey Wadsworth

Jeffrey Wadsworth
President and CEO
Battelle

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The Business of Innovation

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2013 Global *R&D Funding Forecast*

Asia Drives Growth in 2013 Global R&D

U.S. and Europe expect R&D increases that won't match 2013 inflation.

Global R&D spending is forecast to grow by 3.7%, or $53.7 billion in 2013 to $1.496 trillion, according to research by analysts at Battelle, Columbus, Ohio, and *R&D Magazine*, Rockaway, N.J. The largest share of this increase, $22.9 billion, is expected to come from China, which continues its decade-long annual double digit increases in R&D investments.

Plagued by massive debts and weak overall economies, the combined government and industrial R&D organizations of the U.S. and Europe will both fail to even match their projected inflation rates of 1.9% and 1.5%, respectively, in 2013. And while China's economy is starting to heat up with a projected inflation of 3.6% in 2013, its expected GDP growth of 8.2% and R&D growth of 11.6% will continue to move it toward a leadership role in both areas in the near future.

This year's report is the 55th annual *R&D Funding Forecast* created by *R&D Magazine* and the 19th done jointly with Battelle. Reflecting upon the increasingly global nature of the R&D enterprise, this year's forecast includes an analysis of the top 111 countries investing in R&D, from the multi-hundred billion dollar investments of the U.S., China, and Japan, to the $10 million annual investments of Bosnia and Trinidad. This deep analysis was done to more precisely determine the global size of R&D and understand regional growth patterns. In performing this research, we found that 97.3% of the R&D performed in the world is performed in the Top 40 countries listed on page 5. As in previous years, there was a slight shuffling of countries in the Top 40 list with four newcomers in 2013 (Iran, Qatar, Pakistan, and the Ukraine) replacing Saudi Arabia, Romania, New Zealand, and Greece who were listed in the 2012 Top 40.

Share of Total Global R&D Spending

	2011	2012	2013
Americas (21)	34.8%	34.3%	33.8%
U.S.	29.6%	29.0%	28.3%
Asia (20)	34.9%	36.0%	37.1%
Japan	11.2%	11.1%	10.8%
China	12.7%	13.7%	14.7%
India	2.8%	2.8%	3.0%
Europe (34)	24.6%	24.0%	23.4%
Rest of World (36)	5.7%	5.7%	5.7%
Numbers in parenthesis indicate number of countries in that group			

Source: Battelle, *R&D Magazine*

Global trends

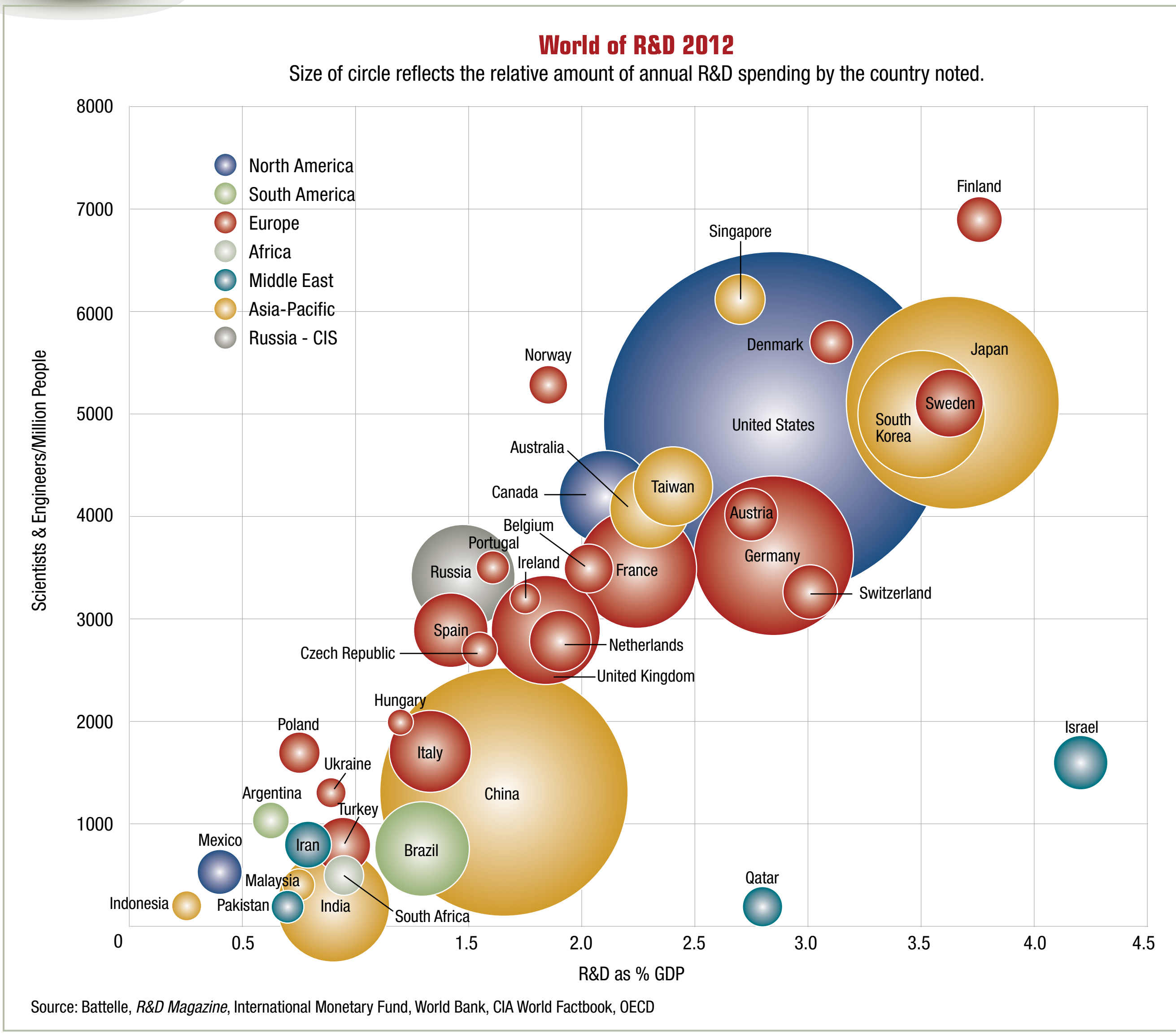
The 2013 *Global R&D Funding Forecast* contains detailed summaries of the major R&D spending organizations, regions, and researcher profiles. It's important to note the long-term effects of R&D investments and their close relationship to economic growth that are considered in this report. R&D is not an instrument that can be quickly turned on and off to trigger economic growth. Many countries and regions have set long-term R&D goals that have not been realized. Ten years ago, the European Union (EU) set a goal of having 3.0% of its GDP invested in R&D by 2010. Due to weak policies, that ratio stagnated and is now less than 1.9%. The EU's new 8th Framework Programme, which begins a year from now, has reset the 3.0% goal for 2020. On the other side, China established a consistent pattern of double-digit R&D fund-

Global R&D Spending Forecast

	2011 GERD PPP Billions U.S. $	2011 R&D as % of GDP	2012 GERD PPP Billions U.S. $	2012 R&D as % of GDP	2013 GERD PPP Billions U.S. $	2013 R&D as % of GDP
Americas (21)	485.4	2.05%	494.9	2.04%	507.6	2.04%
U.S.	412.4	2.70%	418.6	2.68%	423.7	2.66%
Asia (20)	487.1	1.75%	518.6	1.77%	554.6	1.79%
Japan	156.0	3.47%	159.9	3.48%	161.8	3.48%
China	177.3	1.55%	197.3	1.60%	220.2	1.65%
India	38.4	0.85%	40.3	0.85%	45.2	0.90%
Europe (34)	342.9	1.87%	346.7	1.88%	349.5	1.88%
Rest of World (36)	78.8	0.86%	82.3	0.87%	86.4	0.87%
Global Total	1,394.3	1.76%	1,469.0	1.77%	1,496.1	1.77%
GERD, Gross Expenditures on R&D; PPP, Purchasing Power Parity *Numbers in parenthesis indicate number of countries in that group*						

Source: Battelle, *R&D Magazine*

2013 Global *R&D Funding Forecast*



ing increases in the 1990s and over the past 20 years has risen from R&D obscurity to challenging the U.S. (and likely succeeding) for global R&D leadership.

In our increasingly technology-dependent world, strong continued support of R&D investments is essential to maintain and grow a nation's economic strength. It is well-established that technological change is accelerating and without the tools, knowledge, and expertise to build upon those changes, a nation will quickly fall behind those that do invest in innovation.

In the industrial R&D arena, the once indomitable pharmaceutical giants now face challenges driving growth from their product pipelines. In the aerospace-defense area, expensive supersonic stealth fighter jets are being replaced with much less expensive remotely piloted armed aerial vehicles. In the materials industry, nanotechnology breakthroughs routinely occur that cause whole new categories of materials to be developed. And in the energy industry, new technologies can change a nation's long-term economic future. Ten years ago, fracking technologies for recovering shale gas deposits were relatively unknown. Today they promise to change the future of the U.S. economy, complemented by technologies being developed to mitigate the environmental effects of this process.

At the core of this R&D is the basic research performed in academic institutions around the world. For more than 65 years, the bastion of basic research has been the 127 U.S. research universities (classified by the Carnegie Foundation) that account for more than 80% of the federally funded research. But even this cornerstone of R&D is under attack by the economic uncertainties of federal and industrial funding, the rapid growth and funding of foreign universities, and staffing challenges. U.S. academia's share of published scientific papers continues to slip, while the foreign share continues to rise—with China's share doubling to more than 11% over the past five years.

Forecast Gross Expenditures on R&D (GERD)

Billions of U.S. Dollars

		2011			2012			2013		
		GDP PPP Bil, US$	**R&D** as % GDP	**GERD** PPP Bil, US$	**GDP** PPP Bil, US$	**R&D** as % GDP	**GERD** PPP Bil, US$	**GDP** PPP Bil, US$	**R&D** as % GDP	**GERD** PPP Bil, US$
1	United States	15,290	2.70%	412.4	15,626	2.68%	418.6	15,955	2.66%	423.7
2	China	11,440	1.55%	177.3	12,332	1.60%	197.3	13,344	1.65%	220.2
3	Japan	4,497	3.47%	156.0	4,596	3.48%	159.9	4,651	3.48%	161.8
4	Germany	3,139	2.85%	89.5	3,167	2.87%	90.9	3,196	2.85%	91.1
5	South Korea	1,574	3.40%	53.5	1,616	3.45%	55.8	1,675	3.45%	57.8
6	France	2,246	2.21%	49.6	2,248	2.24%	50.4	2,257	2.24%	50.6
7	India	4,515	0.85%	38.4	4,736	0.85%	40.3	5,020	0.90%	45.2
8	United Kingdom	2,290	1.81%	41.4	2,281	1.84%	42.0	2,306	1.84%	42.4
9	Russia	2,414	1.48%	35.7	2,503	1.48%	37.0	2,598	1.48%	38.5
10	Brazil	2,324	1.20%	27.9	2,359	1.25%	29.5	2,453	1.30%	31.9
11	Canada	1,414	1.95%	27.6	1,441	2.00%	28.8	1,470	2.10%	30.9
12	Italy	1,871	1.30%	24.3	1,828	1.32%	24.1	1,815	1.32%	24.0
13	Australia	926	2.25%	20.8	957	2.28%	21.8	985	2.30%	22.7
14	Taiwan	887	2.35%	20.8	899	2.38%	21.4	934	2.40%	22.4
15	Spain	1,432	1.40%	20.0	1,411	1.42%	20.0	1,392	1.42%	19.8
16	Sweden	387	3.62%	14.0	392	3.62%	14.2	400	3.62%	14.5
17	Netherlands	713	1.87%	13.3	709	1.90%	13.5	712	1.90%	13.5
18	Turkey	1,087	0.90%	9.8	1,120	0.90%	10.1	1,159	0.95%	11.0
19	Switzerland	344	3.00%	10.3	347	3.00%	10.4	352	3.00%	10.6
20	Israel	238	4.20%	10.0	245	4.20%	10.3	253	4.20%	10.6
21	Austria	356	2.75%	9.8	359	2.75%	9.9	363	2.75%	10.0
22	Singapore	319	2.60%	8.3	326	2.65%	8.6	335	2.70%	9.0
23	Belgium	419	2.00%	8.4	419	2.03%	8.5	420	2.03%	8.5
24	Iran	1,003	0.79%	7.9	994	0.79%	7.9	1,002	0.79%	7.9
25	Finland	198	3.83%	7.6	198	3.80%	7.5	201	3.75%	7.5
26	Mexico	1,683	0.38%	6.4	1,747	0.39%	6.8	1,808	0.40%	7.2
27	Denmark	209	3.05%	6.4	210	3.08%	6.5	213	3.10%	6.6
28	Poland	782	0.72%	5.6	801	0.72%	5.8	818	0.75%	6.1
29	Qatar	184	2.80%	5.2	196	2.80%	5.5	205	2.80%	5.8
30	South Africa	562	0.95%	5.3	577	0.95%	5.5	594	0.95%	5.6
31	Norway	269	1.85%	5.0	277	1.85%	5.1	284	1.85%	5.3
32	Argentina	726	0.58%	4.2	745	0.61%	4.5	768	0.63%	4.8
33	Czech Republic	289	1.55%	4.5	286	1.55%	4.4	288	1.55%	4.5
34	Portugal	252	1.65%	4.2	244	1.67%	4.1	242	1.60%	3.9
35	Pakistan	495	0.67%	3.3	520	0.69%	3.6	546	0.70%	3.8
36	Malaysia	453	0.70%	3.2	473	0.70%	3.3	495	0.75%	3.7
37	Ireland	184	1.75%	3.2	185	1.75%	3.2	187	1.75%	3.3
38	Indonesia	1,139	0.15%	1.7	1,207	0.20%	2.4	1,283	0.25%	3.2
39	Ukraine	334	0.88%	2.9	344	0.89%	3.1	356	0.90%	3.2
40	Hungary	198	1.20%	2.4	196	1.20%	2.4	198	1.20%	2.4
Subtotal (Top 40)		69,082	1.97%	1,358.1	71,117	1.98%	1,404.8	73,533	1.97%	1,455.5
Rest of World		9,943	0.36%	36.2	10,346	0.36%	37.5	10,782	0.38%	40.6
Global Spending		79,025	1.76%	1,394.3	81,463	1.77%	1,442.3	84,315	1.77%	1,496.1

Source: Battelle, *R&D Magazine*, International Monetary Fund, World Bank, CIA World Factbook

2013 Global *R&D Funding Forecast*

The Uncertain State of U.S. R&D

The watchword heading into 2013 is uncertainty, and the effect on the U.S. research and development enterprise is more unclear than ever. The current economic condition and uneasy prospects for the future combined with a federal government funding projection that could range anywhere from flat to significant declines have limited the prospects for 2013.

The Battelle/*R&D Magazine* team currently forecasts that U.S. R&D expenditures will grow by 1.2%, from our final 2012 estimate of $418.6 billion to $423.7 billion in 2013. Compared to an OMB estimated 1.9% inflation rate for 2013, this level of growth in R&D spending leads to a decline in U.S. R&D investments of 0.7% in real terms over the next year.

The Source-Performer Matrix

Estimated Distribution of U.S. R&D Funds in 2013
Billions of Current U.S. Dollars (Percent Change from 2012)

Source	Performer: Federal Gov't	FFRDC	Industry	Academia	Non-Profit	Total
Federal Government	$27.4 *-3.5%*	$16.7 *-0.6%*	$37.1 *-1.3%*	$41.3 *-0.8%*	$6.4 *0.6%*	$128.8 *-1.4%*
Industry		$0.3 *-0.2%*	$256.5 *2.3%*	$3.3 *1.6%*	$1.6 *8.0%*	$261.7 *2.3%*
Academia		$0.1 *-0.1%*		$12.6 *2.1%*		$12.7 *2.1%*
Other Government		$0.1 *-2.2%*		$4.4 *2.0%*		$4.5 *1.9%*
Non-Profit		$0.1 *-1.2%*		$5.1 *4.2%*	$10.8 *5.0%*	$16.0 *4.7%*
Total	$27.4 *-3.5%*	$17.2 *-0.6%*	$293.6 *1.8%*	$66.6 *0.4%*	$18.8 *3.7%*	$423.7 *1.2%*

Source: Battelle, *R&D Magazine*

The underlying foundation of this forecast of U.S. R&D investment is based upon the National Science Foundation's (NSF) *National Patterns of R&D Resources* data—a longitudinal and umbrella data set that makes the required estimations based on the results from the various NSF R&D expenditure surveys to create a cohesive statement of accounts of the U.S. R&D enterprise. The most recent complete release of this database includes calendar year data estimates through 2009. This data set establishes the specific metric of Gross Domestic Expenditures on R&D (or GERD) for the U.S. Thus, the data captured within the *National Patterns* data set specifically estimates R&D performance occurring in the U.S., regardless of the type or ownership (including foreign) of the performer.

Other recent NSF survey releases and *InfoBriefs* are also used, including the *Business R&D and Innovation Survey* (BRDIS), the new *Higher Education Research and Development* (HERD) survey that provides detailed academic R&D expenditures through FY 2010, and its companion survey that collects data from the various Federally Funded Research and Development Centers (FFRDCs) also through FY 2010.

These new and enhanced data are used to develop and revise estimates for calendar years 2009 to 2012. The 2013 R&D spending forecast incorporates additional information included in various sections of this report, including information regarding federal R&D budgets, corporate R&D expenditures and plans, and the overall condition of the U.S. and global economies.

The Source-Performer Matrix

The U.S. forecast is presented as the source-performer matrix, detailing the flow of funds between specific funding sources and specific R&D performers. The components of the matrix are identified by the NSF through its various surveys of R&D expenditures. The most notable component of the matrix is that four key sources of R&D funding—the federal government, industry, academia, and non-profit organizations—also perform R&D activities. Additional funding flows to academia from other government entities (state and local). A fifth set of R&D performers, FFRDCs, are often operated on a contract basis for the federal government by industrial firms, non-profit research institutes, or universities. While these FFRDCs are operated and managed toward federal R&D missions, many also collaborate with and provide research and technical services to the private sector.

Significant Factors and Assumptions

This 2013 forecast of U.S. R&D investments and performance, as represented in the source-performer matrix, is affected by various factors and assumptions. Six key factors are identified that shape the components of this forecast, but none more than the first.

Slow growth and uncertain plans

Though the state of the U.S. economy is somewhat better than at the end of 2011, the lack of a pronounced growth surge has not only dampened 2012 growth, but has continued a level of uncertainty regarding growth plans for 2013. More than a third of our respondents (from a late Q3 survey) say they are more optimistic about 2013; a third say they are more pessimistic. Of industry survey respondents, 46% expect to increase their R&D expenditures in 2013, while 29% expect decreases. University researchers are even less optimistic about 2013, with 54% expecting decreases in their R&D spending in 2013—likely tied to assumptions about federal R&D investment in 2013 and beyond.

Dampened industry R&D trajectory

By the end of Q1, 2012, it became apparent that the overall economic malaise would continue to be a restrictive force on overall industrial R&D much longer than previously forecast. An anticipated Q4 2011 R&D investment spike failed to materialize as firms waited to see if economic conditions in 2012 provided a spur to invest. Additionally, the anticipated return of U.S. industrial R&D to pre-recession levels has not materialized, and is now unlikely until perhaps late 2013.

Flat federal R&D budgets or worse

The *Budget Control Act* of 2011 (BCA) has imposed mandatory limits on department and agency R&D budgets for 2013. These spending caps limit the ability of Congress to even allow overall budgets to keep pace with inflation. Compounding the difficulty in establishing federal R&D budgets, the federal government is once again operating under a continuing resolution (CR). This CR extends until March 27, 2013, tying FY 2013 spending to FY 2012 levels for now. As in previous years, if budget negotiations prove difficult, the final federal R&D budgets for FY 2013 could ultimately be finalized at roughly these levels.

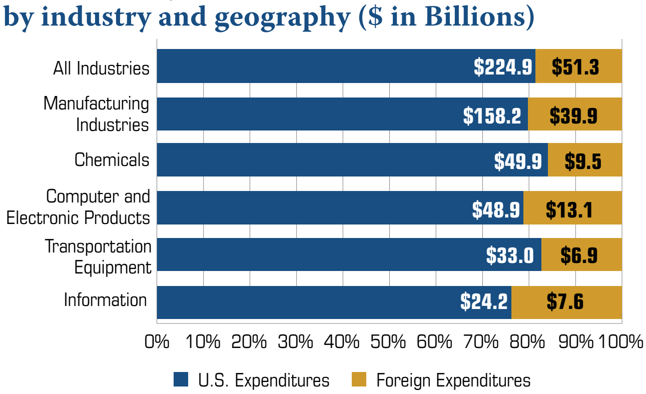
Avoiding the "fiscal cliff"

For this forecast the Battelle/*R&D Magazine* team assumed that some level of compromise regarding the federal "fiscal cliff"—the combination of expiring tax credits and the impact of the impending sequestration, or automatic budget cuts—will either be reached or its effects delayed beyond January 2, 2013. From an R&D perspective, a number of organizations, including the American Association for the Advancement of Science (AAAS) and the Information Technology & Innovation Foundation (ITIF), have performed interesting and detailed analyses of the short- and long-term budgetary impacts of the sequestration on federal R&D and the overall economy. From a forecast perspective, such a funding "event" would uniquely change the long-term inertia and stability that is a cornerstone of U.S. R&D investment.

Improved corrections for non-U.S. R&D

The release of the 2009 BRDIS data provides a clearer, though still limited, perspective on the size of U.S. corporate R&D expenditures in foreign operations. The ability to analyze trends, especially given the recession's impacts on the 2009 data, remains difficult with only two years of data. However, the NSF data reveals that on average U.S. firms (or U.S. locations of foreign companies) spent slightly more than 80% of their 2009 R&D investments here in the U.S. versus in foreign locations. The BRDIS data now allow for an improved estimation of the share of U.S. industry R&D growth that should be included within the industry expenditures forecast.

Worldwide R&D Expenditures for R&D performed by U.S. companies, by industry and geography ($ in Billions)

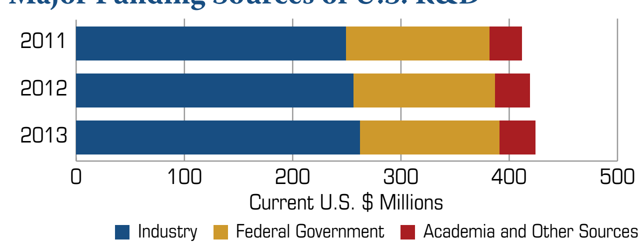


Source: NSF Business R&D and Innovation Survey, 2009

Other enhancements to NSF data

Other NSF surveys released later in 2012 have added enhancements and extensions that will likely be reflected in the next release of the *National Patterns* data. One component change stems from a full assessment through the new HERD survey of R&D expenditures by academia outside of the traditionally measured science and engineering (S&E) fields. It is estimated that the inclusion of non-S&E R&D will likely add $3 to 4 billion to overall U.S. academic R&D levels, and hence, overall U.S. levels. Likewise the companion survey of FFRDCs provides additional insights into the actual levels of federal funding and other sources of research funding and how this differs among laboratories' various management structures.

Major Funding Sources of U.S. R&D



Source: Battelle, *R&D Magazine*

Details on U.S. R&D Funding Sources

The description and analysis of the 2013 forecast begin with a discussion of the major sources of U.S. R&D funding. This discussion focuses on the overall magnitude, nature, and distribution of these funds to the various performers.

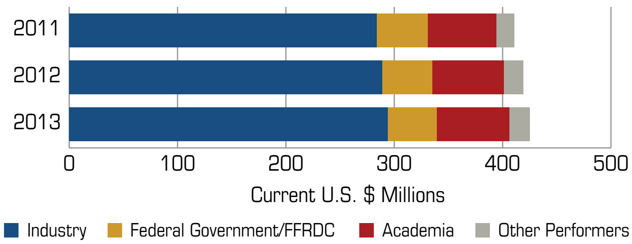
Federal Funding of R&D

The ongoing budget and deficit concerns will continue to strain the ability of the federal government to invest in R&D efforts. At this point in time, though research and development funding has strong bipartisan support, fiscal realities and the spending caps put in place by the BCA will ultimately reduce total funds for federal R&D in 2013.

With the final federal FY 2013 R&D budgets likely guided by the current continuing resolution and held in check by the BCA, our forecast, building upon the work of the Office of Science and Technology Policy (OSTP) and analysis from AAAS, expects federal funding for 2013 to reach $128.8 billion, a decline of 1.4% from our final 2012 estimated federal R&D funding level of $130.7 billion. This level of federal R&D funding will constitute 30% of overall U.S. R&D funding in 2013.

2013 Global *R&D Funding Forecast*

Major Performers of U.S. R&D



Source: Battelle, *R&D Magazine*

Industry Funding of R&D

Industry funding for R&D in the U.S. is subject to a high level of uncertainty, both in overall growth and where this growth should occur. Under our assumptions, industrial funds for U.S. R&D will reach $261.7 billion in 2013, a slight increase of 2.3% from our final 2012 estimate of $255.9 billion. Much of this growth is from the core inertia inherent in the longer-term funding requirements of corporate R&D. At this level, industry R&D is the most significant component of overall U.S. R&D investment, accounting for 62% of the total.

As with previous years, 98% of this funding stays within industry R&D operations, either as internal R&D or to other U.S. industrial R&D contractors. Forecasting where industry will make the remaining $5.2 billion in R&D investments remains a challenge. Trends toward open innovation have been mostly limited to sharing available intellectual property portfolios rather than sharing R&D financial resources—not surprising given the current economic conditions. We continue to see potential for growth in industrial funding to academia and non-profit R&D operations, but at a very modest scale. If economic conditions worsen in 2013, these investments will be some of the first to be cut back.

Other Funding of R&D

The remaining 8%, or $33.2 billion, of U.S. R&D investment comes primarily from self-funding sources, grants from non-profit organizations (typically foundations) and state, local, and other governments. These funding sources, though a small component of overall U.S. R&D funding, provide both focused resources for specific areas (for example, multiple sclerosis research funded by the National MS Society or Parkinson's research funded by the Michael J. Fox Foundation) or provide intramural resources for very early stage or capability development research within academic institutions. Combined, these other funding sources are forecast to increase by 3.3% over our final 2012 estimate of $32.1 billion.

Details on U.S. R&D Performers

Examining the performance dimension of the 2013 source-performer matrix leads to a more detailed understanding of the role that the federal government (including the FFRDCs), industry, academia, and non-profit organizations play in the U.S. R&D enterprise.

Federal Performance of R&D

The continued budget pressures and cuts in federal R&D funding will once again impact the performance of intramural research by federal departments and agencies. We forecast federal intramural research to reach $27.4 billion in 2013, declining by 3.5% from our final 2012 estimate of $28.4 billion. With this decline exceeding the overall federal funding decline of 1.0%, federal intramural R&D performance will be at its lowest ***current dollar*** level since 2005.

FFRDC Performance of R&D

As we began last year, we attempt to better describe the resources leading to the performance of R&D by the FFRDCs. We forecast that FFRDCs will perform $17.2 billion in R&D activities in 2013, a decline of 0.6% from our final 2012 estimate. Within these resources, the FFRDCs continue to operate principally with their federal resources—more than 97% of their funding comes from the federal government. The remaining funds include more than $250 million from industry—representing both contract research activities and funds from some FFRDC industry operators.

Industry Performance of R&D

Total industry R&D performance is forecast to reach $293.6 billion in 2013, a slight 1.8% increase over our final 2012 estimate of $288.5 billion, but still a decline in real terms. Federal funding for industry R&D will be affected like most recipients of federal R&D funds. The overall federal spending on industry R&D will decline by 1.3%, reaching $37.1 billion in 2013, with much of this decline reflecting continued reductions in federally funded defense R&D. This represents the third straight year with declining levels of federal R&D funds to industry.

Academic Performance of R&D

We forecast a slight 0.4% increase in academic performance of R&D, reaching $66.6 billion in 2013 compared to our final 2012 estimate of $66.4 billion. As 2012 ends and 2013 begins, all remnants of spending increases due to ARRA have been removed, and academic R&D expenditure levels, dominated by federal funding, begin to stabilize on a new, flatter growth trajectory. Federal funding for academic R&D is forecast to decline by 0.8% to $41.3 billion in 2013. In real terms, the federal investment in academic research will decline by 2.7%.

Increases in other sources of funding for academic R&D will mitigate these effects somewhat. Institutional internal funding will increase by 2.1%, reaching $12.6 billion in 2013. This increase comes as some institutions look to reduce the effect of uncertain federal funding on key research programs and faculty while other institutions begin to establish variations on the "grand challenge" theme to provide resources and structure to future research endeavors.

The economic realities of 2012 and uncertainties of 2013 have tempered our expectations for increasing levels of collaborative R&D between industry and academia leading to a slight 1.6% increase in industry support for academic R&D in 2013, reaching $3.3 billion.

Non-Profit Performance of R&D

We forecast R&D performance by non-profit organizations to increase by 3.7%, reaching $18.8 billion in 2013. The largest dollar increases will come from within the non-profit community itself. Technology R&D organizations will invest internal R&D funds to keep promising research programs active during periods of federal funding uncertainty.

FY 2013 U.S. Federal R&D Funding: Uncertain Future

With significant fiscal debates ongoing, a detailed discussion of FY 2013 federal R&D funding would be of limited value at this time. Instead we highlight a few key issues and describe how the current budget will likely be developed. For an up-to-date analysis of federal R&D appropriations, we recommend the AAAS R&D Budget and Policy Program.

Continuing Resolutions

The federal government is currently operating in FY 2013 under a continuing resolution (CR) set to expire March 27, 2013. The CR sets the current fiscal year budget at the final enacted levels of the previous fiscal year's budget, with only slight modifications possible.

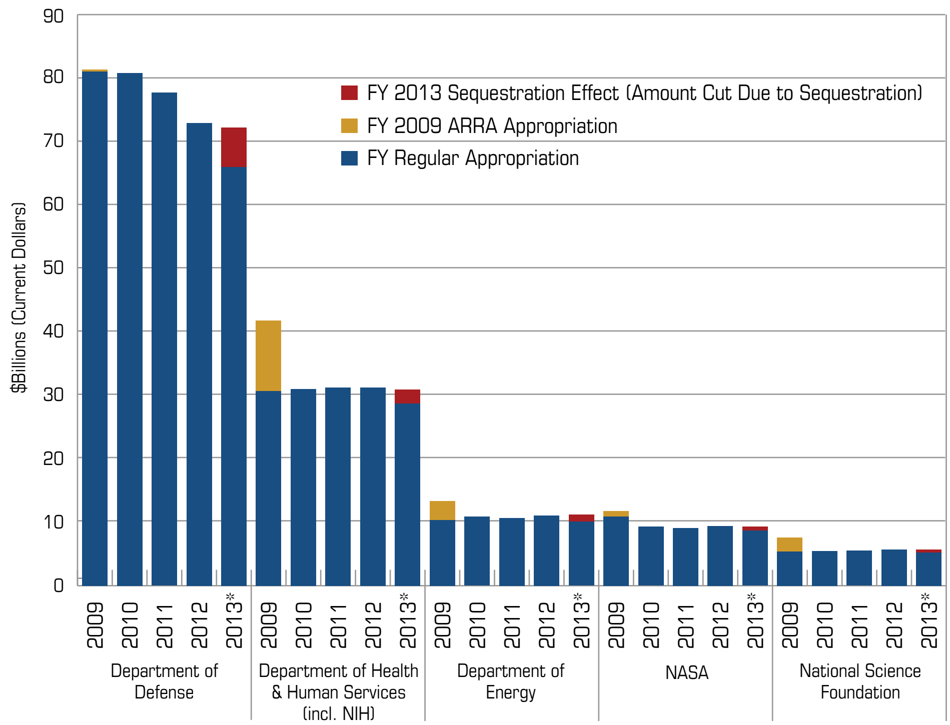
Unlike previous years, this year's CR was established under the fiscal controls mandated under the *Budget Control Act* of 2011 (BCA), including spending limits or caps on future budgets. The BCA was also responsible for the creation of the congressional Joint Select Committee (the "Super Committee"), which failed to reach a compromised budget agreement last year (2011). This failure automatically invoked a budget sequestration to begin January 2, 2013—one of the key components of the "fiscal cliff" currently under debate.

Similar to previous years, there is a strong likelihood that most, if not all, federal departmental budgets will be established through an Omnibus appropriations bill, making spending levels under the current CR the final full-year budget. In a somewhat ironic twist, if the current CR functions as the ultimate FY 2013 "budget", the slightly higher spending caps established under the BCA for FY 2013 will actually provide a slight (less than 1%) increase over FY 2012 levels.

Declining Real Dollar Outlook

Based on this scenario, the current CR-based FY 2013 would indicate a federal R&D budget of $140.0 billion, up 0.8% from the final FY 2012 of $138.9 billion. This budget takes into account several small modifications beyond the slight increase allowed by the BCA, including mandatory increased spending for nuclear defense R&D within the Department of Energy. With a projected 2013 inflation rate of 1.9%, however, the estimated budget is still declining by more than 1% in real terms over FY 2012.

Recent R&D Appropriations for Key Federal Departments and Agencies



Source: Battelle/*R&D Magazine* estimates with data from OSTP, AAAS

Potential Sequestration Effects

Though not considered in the U.S. R&D Forecast figures, this discussion of the FY 2013 budget would be incomplete without some mention of the potential effects of sequestration on federal R&D spending. In its most simple description, the sequestration is basically a "resetting" of the baseline federal budget for defense and nondefense discretionary spending, with formula-based spending caps limiting the potential for future-year budget growth.

If the budget sequestration takes effect in January 2013, the effect on federal FY 2013 R&D spending is estimated by AAAS to equal a reduction of $12.1 billion. Of this total, approximately $6.9 billion of these cuts will come from the Department of Defense and $2.4 billion will come from the National Institutes of Health. The column chart shows the FY 2009 to FY 2013 R&D funding of the five largest R&D performing federal departments and shows the effects of sequestration on the estimated CR-based FY 2013 budget. As the chart shows, the first year impact, though substantial, is a smaller one-year amount than the ARRA-based increases in R&D funding in FY 2009 for several agencies. However, the longer-term cumulative reduction in federal R&D investment and the lasting impact it would have on overall U.S. research competitiveness are the issues of greatest concern.

Expenditure Impacts of U.S. R&D

R&D is generally a long-term investment, building upon the results of previous years' expenditures, leading first to the generation of new knowledge through basic research and ultimately to products and services through applied research, development, and commercialization. These are considered to be *functional* impacts—benefits that occur as a function of the R&D's completion and often at a scale much larger than the original investment. There also are important *economic* impacts that relate directly to the annual R&D investment and the related multiplier or "ripple" effects of this spending through the economy.

Real-time Economic Impact of R&D

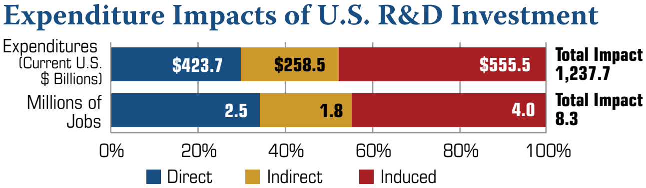
Various budgetary analyses have been performed on federal spending and the long-term effects of funding reductions. Other analysis has assessed the functional and economic impacts of long-term federal R&D investments (for example, the *Economic Impact of the Human Genome Project* published by Battelle). A pragmatic examination of the economic impacts of annual total R&D spending, however, has not been developed. This type of analysis is particularly relevant when Congress and the administration must make choices among competing uses of scarce funds. By estimating the potential economic impacts of annual U.S. R&D expenditures, we hope to add to the discussion regarding the importance of R&D to the U.S. economy by attaching a concrete "measurable" to the value of annual R&D investment to the *current* economy. This analysis makes no attempt to establish R&D's total functional value, but focuses only on the economic effect of the current year's spending on the current year.

Significant Current Year Expenditure Impacts

We estimate that the 2013 forecast of $423.7 billion in U.S. R&D expenditures will directly employ 2.47 million full- and part-time U.S. workers and will support, through the ripple effect of these expenditures, the ultimate employment of 8.27 million U.S. workers in 2013. These total expenditures will also generate $1.238 trillion in the U.S. economy through the purchasing activities of these R&D performers, their suppliers, and their workers. It is important to note that this is a single-year expenditure-based analysis and these results **do not include** the workers or revenue/output associated with **producing any product resulting** from past or current R&D activities.

These results indicate that on an expenditure basis alone, the U.S. R&D enterprise has a significant impact on the U.S. economy and is a substantial "real-time" economic and employment driver for the nation. It also shows that when contrasting the potential longer-term benefits of R&D to current budgetary constraints, it is important to consider that the U.S. R&D enterprise consists of real jobs and economic impact—now.

Expenditure Impacts of U.S. R&D Investment



Source: Battelle, *R&D Magazine*

Comparison of Industry Economic Impact Multipliers

Industry	Jobs per $Million Industry Output		Total Multipliers	
	Direct *Industry*	Total	Output	Employ-ment
Aircraft	1.6	9.9	3.0	6.2
Automobiles	0.8	9.2	2.7	12.2
Computers	0.6	8.6	2.8	14.1
Comp. Services	11.5	30.7	2.1	2.7
Iron and steel	1.4	10.9	2.7	7.5
Pharmaceuticals	1.8	10.6	3.1	6.0
Scientific R&D	5.8	19.5	2.8	3.4
Software	1.9	12.3	2.6	6.4

Source: 2010 U.S. IMPLAN Economic Impact Model

Methodology for Measuring R&D Impacts

In our economic model, we used the scientific R&D sector as a surrogate for all R&D activities. To that surrogate we applied total public and private R&D spending. Typically, this economic sector consists solely of standalone R&D operations, ranging from small startups to firms such as Battelle. For simplicity, this approach also models all R&D expenditures the same—spending on pharmaceutical R&D is treated the same as automotive R&D, and likewise the same as university and government R&D. While there are differences in the research being undertaken, there are strong similarities in the economic structure and purchases among these different performers—often more so than R&D has with the other activities of a firm or industry. This commonality is strong enough to warrant a focused publication, *R&D Magazine*. For example, from a purchasing perspective automotive R&D has more in common with pharmaceutical R&D than automotive R&D has with automotive industry *production* activities—automotive R&D does not buy billions of dollars of steel and glass, but rather computers, laboratory instrumentation, scientists, and engineers.

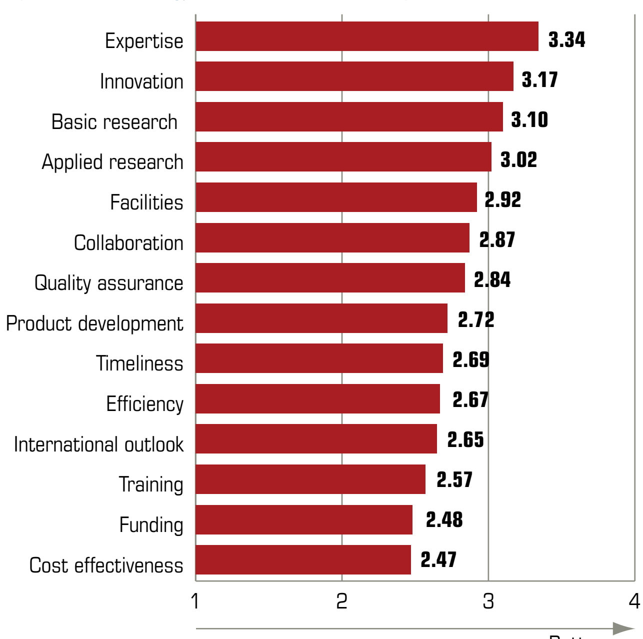
This conservative analysis is based on the application of certain economic impact ratios and multipliers (developed using a 2010 U.S. IMPLAN economic impact model, the most current available). To understand its conservative nature, a comparison of other "industry" multipliers is provided. As a service industry, scientific R&D generates more jobs per $million in output than manufacturing industries where automation and other productivity enhancements increase the output per worker. In terms of total (including multiplier effects) employment or output impacts in the economy, the values associated with scientific R&D are smaller than many "high-tech" industries. This indicates that using the scientific R&D sector as a surrogate for all R&D will likely provide a more conservative and more appropriate measurement than applying R&D expenditure values across all segments of the economy.

Academic R&D Growth Slows

The amount of R&D funded by U.S. academia is forecast to increase by 2.1% in 2013 to $12.7 billion. The amount of R&D performed by U.S. academia (funded by all sources) is expected to increase by 0.4% to $66.6 billion. Both of these values generally are well below 3% or larger range in previous Global R&D Funding Forecasts. This year's reduced funding and performance reflects 1) reduced government support due to across-the-board spending cuts, 2) slower economic growth in the U.S., and 3) the termination of ARRA (American Recovery and Reinvestment Act of 2009) funds which, after three years allowed for distributing roughly $18 billion in R&D stimulus funds, finally ran out in 2012.

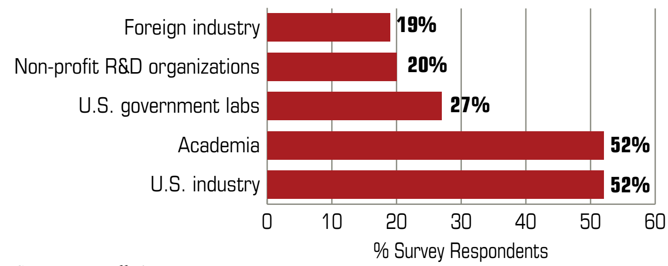
Academia is one of the crown jewels of U.S. R&D. It is where more than 60% of the basic research in the U.S. is performed—75% of the research in universities is basic and 22% is applied. Academia also produces more than two-thirds of the scientific papers published in the U.S. And as noted above, it is where the U.S. government and industry annually outsource more than $50 billion worth of R&D. The quality of U.S. academia is also well recognized, with the majority of the top 100 global academic institutions ranked by independent organizations being in the U.S., according to a study by Thomson Reuters. The study also found that a significant amount of research (as measured by the output of published scientific papers) is concentrated in the top U.S. universities. Each of the top 25 U.S. schools, for example, produces well over 1% of the total U.S. output of scientific papers. These schools also received nearly half of all citations to U.S. papers, averaging over 22 citations/paper.

Researchers Grade Academic R&D



Source: Battelle/*R&D Magazine*

Most Effective Organizations for Technology Collaborations



Source: Battelle/*R&D Magazine*

Competitive Environment

China produces more science-based doctorates than those awarded at U.S. universities. Besides population differences, the weak U.S. economy contributes to the gap as educational choices align with employment opportunities. For example, the 19,700 scientific doctorates awarded in the U.S. in 2009 exceeded the available jobs. A similar situation is evident in China, where scientists with good undergraduate degrees can earn up to 30% more than candidates with Ph.D. degrees. More than half the Ph.D.s awarded in the U.S. are employed in academia, 13% in government, and about a third in industry.

Chinese universities are aggressively recruiting leading researchers from top U.S. universities, targeting those leading world-class research projects. They also offer more than half of their graduate courses in English.

For more than a decade, concerns have been voiced in the U.S. that too few undergraduate students are choosing to specialize in science and technology fields, but a major supply crisis has yet to materialize. Part of this reaction was due to a declining number of students in the population about 10 years ago, which has now reversed. Enrollments in universities are now increasing.

Funding Concentration

One concern for U.S. academia is its heavy reliance on government and industry funding—for 2012, 62% of academic funding came from the federal government. State funding of academia has stagnated or declined over the past decade due to economically strapped state budgets. And now, with the possible automatic budget cuts due to the *Budget Control Act* of 2011 sequestration issues, federal support for academia could be facing up to 9% cuts as well in 2013. These cuts could result in 2,300 fewer grants awarded by the U.S. National Institutes of Health (NIH) alone.

According to a recent survey by *R&D Magazine*, academia is the most effective type of research organization for technology collaborations and outsourcing. However, the survey respondents also indicated that academic facilities, expertise and funding are likely to get slightly worse over the next three years than they are now.

Another weakness is that the research base appears to be concentrated in the top universities, and it is more concentrated there

than in other countries such as the U.K. Against international competitors, U.S. research universities are losing share and their historic strengths are being challenged, according to the Thomson Reuters report.

Performance

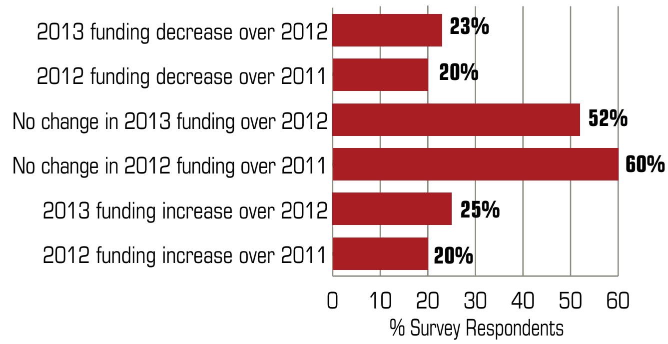
The bleak outlook for federal funding of academic research has resulted in a greater cost sensitivity in university research laboratories. This also could result in extended buying cycles, delayed instrumentation purchases, and reduced project scopes. More academic laboratories are sending their purchase requests out for competitive bids than have ever done so before, according to a recent study by Frost & Sullivan for the Laboratory Products Association (LPA).

The continuing resolution (CR) was passed in September 2012 that extends all government funding through March 27, 2013, at FY 2012 levels plus 0.6%. The NIH decided to award research grants up to 90% of the previously committed level throughout the CR, which is the same as that for the previous CRs through FY 2006.

According to the LPA report, academic laboratories reported an increase in their total budget from 2011 to 2012, but don't expect a further increase in 2013. Purchasing shares across instruments, equipment, chemicals, life science kits, plasticware, and general laboratory supplies are expected to be stable during this period.

Universities with medical schools receive almost 10 times more R&D funding—or about $240 million—than those without. This is a result of the heavy extramural funding provided by the NIH, which has an annual research budget of approximately $31 billion, according to the National Science Foundation.

Academic R&D Budget Changes



Source: Battelle/*R&D Magazine*

Industrial R&D Perspectives and Forecasts

In the following ten pages the Battelle/*R&D Magazine* team presents information on five key industry segments within the U.S. and global R&D enterprise. These five have been examined over the past two forecasts, allowing us to identify and interpret the underlying trends and drivers of these segments' R&D spending.

The data developed for each of these segments include a detailed look at R&D spending of the leading U.S. firms, a discussion of results from our surveys of these segments' firms, our U.S. and global R&D forecasts for each of these segments, and brief narratives describing key developments or issues that will shape the segments' R&D investment plans for 2013.

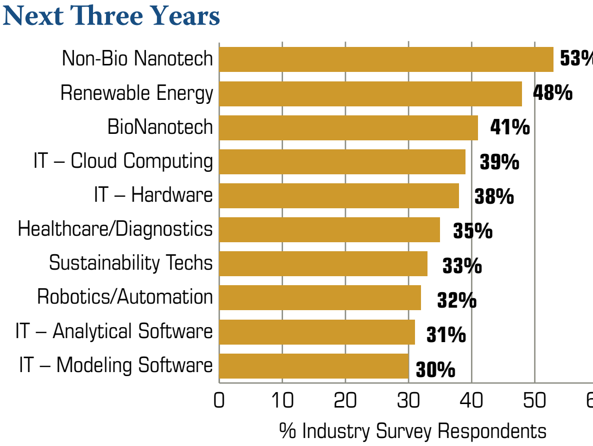
Data for the U.S. leading R&D firms is obtained from public financial reports, with fiscal year quarters adjusted to the closest calendar year quarter. The firms were surveyed over the last six months regarding various aspects of their R&D performance and outlook. The specific forecasts are strongly tied to generally flat U.S. and global economic projections. As they are often leading-indicator industries, a number of these segments could return to more robust pre-recession growth rates if the economy improves more than expected in early 2013.

Economic Concern But R&D Commitment Remains

Industry respondents to our surveys are slightly more optimistic about 2013 than they were about 2012, but 54% of the respondents report that the global economic slowdown has caused them to rethink their 2013 R&D budgets. Still, only 29% of the respondents expect their R&D budgets to decline in 2013. Stable budgets are expected by 25%, with 46% expecting budget increases in 2013 (though the majority of those expect increases of less than 5%).

As expected, salaries will account for the largest share of these 2013 budgets at 48%, with supplies and consumables accounting for 13%. Capital equipment and non-capitalized instrumentation and other equipment will account for 10% and 6%, respectively. Outsourcing or external consultants will capture 7% of the budget. Finally, overhead and other expenditures will account for 10% and 6% of the budget, respectively. Within these staffing budgets, industry respondent's hiring plans are more optimistic than not, with 43% expecting to add R&D staff in 2013, while 24% expect staffing levels to decline.

Key Technologies Driving R&D in the Next Three Years



Source: Battelle/*R&D Magazine*

Industrial R&D—Life Science

Overview

Increasing healthcare costs, aging populations, and rising prevalence of chronic diseases are among the factors that will continue to shape the direction of industrial life science R&D in 2013. Technology deployment in healthcare information technology and analytics will also have an increasing impact on research while contributing to efficiency and quality.

Life science is a diverse global business, but one industry and one country dominate R&D funding. While drug costs amount to 10 to 15% of worldwide healthcare expenditures, pharmaceutical and biotechnology companies comprise the majority of research spending in the life science sector, which also includes medical devices, agricultural biotechnology, and animal health. Innovation remains vital since patent expirations of blockbuster drugs continued in 2012.

Among nations, the United States spends the most on healthcare per capita, as a percent of GDP, and in absolute terms. Public sector payers (notably Medicare) account for nearly half of U.S. expenditures. Considering these factors along with the now-certain implementation of the Affordable Care Act, NIH funding over US$30 billion in research, and the FDA's role as a gold standard for regulatory oversight, it is clear that U.S. public policy will continue to influence global life science R&D.

Leading U.S. R&D Firms

The trend toward reducing R&D investment levels continues among many of the leading U.S. life science firms. Both Pfizer and Merck are currently on track for 2012 investment levels significantly below 2011, with R&D budget decreases of $1.5 billion and $500 million, respectively. Johnson & Johnson will also likely spend less on R&D in 2012 than it did in 2011. Both Lilly and Abbott Labs will likely end 2012 having invested slightly more than in 2011.

One of last year's top ten life science R&D spenders, Biogen Idec is also on track to exceed its 2011 investment level, but its lower spending level removed it from this year's list. One of the largest increases is likely to come from Gilead Sciences, which currently ranks 11th among our leaders. Gilead has already exceeded its 2011 R&D investment total through the first three quarters of 2012, and will very likely enter the top 10 list next year.

Life Science	2010	2011	Q1-Q3 2012
Top U.S. R&D Expenditures	Millions, U.S. $		
Pfizer	9,392	9,112	5,734
Merck & Co.	11,111	8,467	5,945
Johnson & Johnson	6,844	7,548	5,334
Lilly (Eli) & Co.	4,884	5,021	3,815
Abbott Laboratories	3,724	4,129	3,181
Bristol-Myers Squibb Co.	3,566	3,839	2,822
Amgen	2,894	3,167	2,411
Celgene	1,129	1,600	1,251
Medtronic (e)	1,464	1,482	1,167
Monsanto	1,241	1,435	1,166

Source: Battelle/*R&D Magazine* and Current Company Information; (e) = estimated

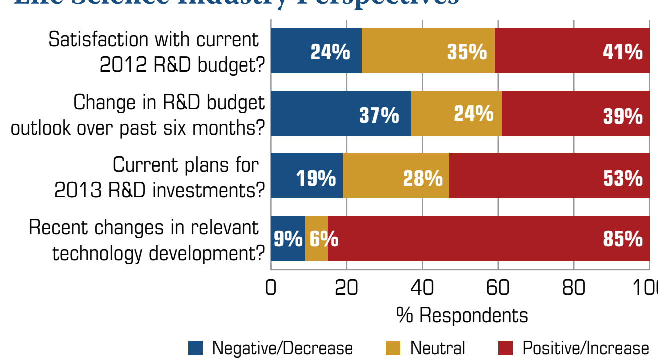
U.S. Industry Perspectives

Life science industry representatives were asked whether they were satisfied with their 2012 R&D budgets. A majority of respondents were positive, though with nearly a quarter negative in their budget perception, the industry as a whole still has concerns over R&D spending levels. This concern is shown with nearly 40% of respondents saying their budget outlook for 2013 became more negative over the last six months. Though their outlook may be cloudy overall, more than half (53%) expect their 2013 R&D budgets to increase over 2012.

With these increasing life science R&D budgets come additional concerns and opportunities. Nearly half (47%), report they expect even tighter budgeting requirements going forward. Over 40% report they will likely be involved in more collaborative research in 2013, and 39% expect their R&D efforts will take on a more global context in 2013.

U.S. life science industry researchers are still optimistic about the state and pace of technology development. More than 80% cite positive developments in life science technologies over the last few years. There is some concern regarding the U.S. leadership in life science R&D—44% of the life science respondents felt U.S. leadership was somewhat at risk, with 17% concerned that U.S. leadership was significantly at risk.

Life Science Industry Perspectives



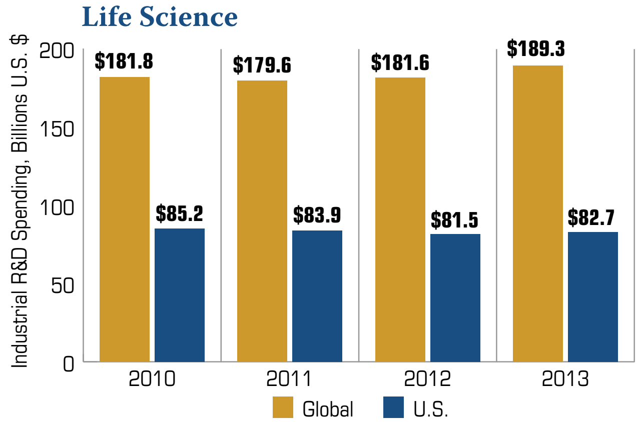
Source: Battelle, *R&D Magazine*

U.S. and Global Industry Forecast

The life science industry has experienced both recession-driven reductions in R&D spending and also a significant shift in the type and distribution of R&D investments by major pharmaceutical firms over the last few years due to fewer products in their pipelines and some shifts to biological rather than small molecule products.

Even with the ongoing reductions in R&D spending by some of the largest U.S. life science firms, we forecast a slight 1.4% increase in total U.S. life science R&D to $82.7 billion in 2013. This U.S. growth, combined with similar lower levels of growth among European life science firms, but significant growth among Asian life science firms, will lead to 2013 global life science R&D spending of $189.2 billion, a forecast increase of 4.2% from 2012 to 2013.

The estimates and forecast show that U.S. industry should turn the corner and begin increasing their R&D investment in 2013. The global industry, while affected by a slowdown from 2009 to 2012 is on a stronger R&D growth trajectory into 2013.



Source: Battelle/*R&D Magazine* estimates and forecast

Promise of Healthcare Information Technologies

Fueled by American Recovery and Reinvestment Act funding as well as incentives and penalties from the Centers for Medicare & Medicaid Services, implementation of electronic health records in the U.S. is now well over half completed. Integrated healthcare information systems are expected to improve efficiency, quality, and clinical decision support, and to become enabling technology for new provider models like Accountable Care Organizations, which are intended to deliver value-based outcomes.

With security and privacy safeguards, analysis of data from these systems also offers great potential to guide and validate R&D in therapeutics and diagnostics, improve prediction and diagnosis in the clinic, and accelerate development and adoption of "connected health" technologies.

Such improvements in life science research and outcomes depend on continued technology development in the field of big data analytics. Having applications in multiple markets, technology and services for big data analysis are becoming an entirely new industry. Information integration and analysis at this scale, however, will require challenging computational research to accommodate data heterogeneity, scale, variable timing and origins, complexity, and security.

"Connected health" is the patient-based, mobile dimension of healthcare information technology. Many believe that this evolution of telemedicine will improve diagnosis and chronic disease management, increase cost-effective, coordinated access to healthcare, and empower healthcare consumers. Data analysis is already underway, such as one project to stratify re-admission risk for heart patients based on monitored wellness and compliance behavior. Other R&D includes adaptation of social technologies and integration from sensors to workflows to enterprise. Venture capital is an important source of innovation funding in this domain.

New Innovation in Diagnosis & Treatment

Enriched access to healthcare information will also accelerate pharmaceutical R&D, particularly when integrated with proliferating data sets from fast biology instrumentation. Techniques like genome-wide association studies could reveal new druggable targets and associated biomarkers. Comprehensive post-marketing surveillance integrated with phenotype data could provide new insight on drug safety. The overall result will be new vectors of attack on major chronic diseases that are drivers of healthcare costs, as well as greater efficiency to stimulate progress on underserved diseases.

Translational science will be another key biopharmaceutical research area in 2013. NIH Director Dr. Francis Collins wrote that "little focused effort has been devoted to the translational process itself as a scientific problem amenable to innovation." With a mission to catalyze private sector R&D, NIH's National Center for Advancing Translational Sciences recently became operational. New translational technologies will model disease and systems biology more effectively, predict drug safety and efficacy earlier and more accurately, and provide clinical biomarkers for diagnosis and prediction of therapeutic response.

The medical device industry has traditionally leveraged venture capital to fund early-stage innovation. The outlook for 2013, however, may follow a recent trend of restraint, with medtech venture investments in the first nine months of 2012 at only 76% of the prior five years' average. Some attribute the issue to pricing and tax uncertainty under the ACA, while others see emphasis on capital-efficiency and ROI. Although some operating decisions have been linked to these uncertainties, research at larger companies appears to be less sensitive. In addition to continuing to develop innovative products in their core markets, companies like GE and Medtronic are making R&D investments to improve value to customers. Partnering is gaining momentum as a risk-managed way to integrate capabilities from multiple domains into increasingly sophisticated devices.

Industrial R&D—Information & Communication Technologies

Overview

Information and communications technology (ICT) continues to evolve into various form factors, platforms, and system configurations. Its expanding applications base includes increasingly high-performance and cloud-based computing systems, a massive infrastructure of mobile communications, global networks of sensing systems, military and defense networks, Internet-based control systems, and many more.

Forty years ago, military funding dominated the initial development of these devices and systems. Today, government R&D funding for ICT is just a quarter of the total, while industrial sources account for about 70% of the nearly $300 billion spent on ICT R&D. Massive infrastructure and personal and corporate reliance on ICT systems also makes them vulnerable to geophysical, terrorist, and accidental threats, driving significant industrial and military R&D efforts to protect these systems.

Large-scale information, semiconductor, and communication systems rely on complex layers of integrated technology. At the same time, the pace of technology development and deployment is accelerating. As a result, even the largest companies increasingly rely on a combination of collaboration, development alliances, intellectual property licensing, and acquisitions to incorporate enabling technologies, ensure performance and security, and mitigate risks.

Leading U.S. R&D Firms

The U.S. continues to drive R&D within the global ICT industry. With major pharmaceutical firms scaling back R&D activities, Microsoft became the largest U.S. R&D spender in 2011. Microsoft, Intel, and IBM are all on pace to exceed their 2011 levels. If Intel's spending increases slightly more than expected through the end of 2012, it could challenge Microsoft as the largest R&D investor. Google's 2012 R&D spending rate has it on track to pass both Cisco and IBM and move into the third position in next year's assessment of U.S. ICT R&D spending. Google has nearly equaled their 2011 investment through the first three quarters of 2012, and is on pace to more than double their 2009 investment level. Apple, whose reputation for innovation demonstrates the sometimes non-linear connection between innovation and R&D spending is also ramping up its R&D, having already exceeded 2011 levels through the first three quarters of 2012. At this pace, Apple will have more than doubled its R&D in four years.

Information & Comm. Technologies	2010	2011	Q1-Q3 2012
Top U.S. R&D Expenditures	Millions, U.S. $		
Microsoft	8,951	9,362	7,571
Intel	6,576	8,350	7,519
International Business Machines	5,720	5,990	4,531
Cisco Systems	5,711	5,628	4,161
Google	3,762	5,162	5,035
Oracle	4,108	4,449	3,572
Hewlett-Packard Co.	3,076	3,242	2,556
Qualcomm	2,504	3,221	1,928
Apple	1,959	2,612	2,623
EMC	1,888	2,150	1,897

Source: Battelle/*R&D Magazine* and Current Company Information; (e) = estimated

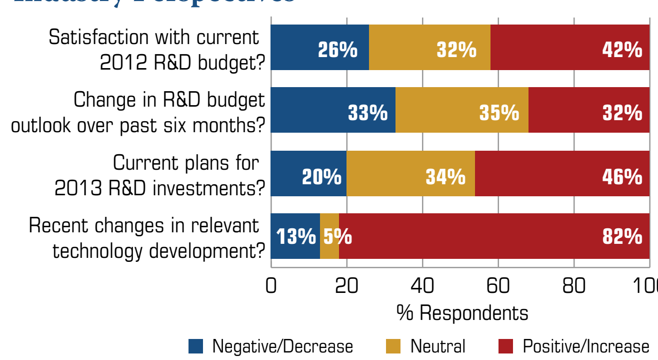
U.S. Industry Perspectives

U.S. ICT professionals, like their life science counterparts, have a mixed perception regarding their R&D budgets. More than one quarter (26%) are not satisfied with their R&D budgets, while more than 40% were pleased with how their 2012 budgets fared. Uncertainty marked the outlook for 2013 R&D budgets, with approximately an equal number of respondents having a negative, neutral, or positive change in their outlook in the last six months. Regardless of how their outlook has changed, ICT respondents are generally positive about 2013 investments, with 46% indicating that they expect an increase in their R&D budgets over last year.

Collaborative development is becoming more prevalent as firms look to extend the capacity of their resources; 44% of the firms expect an increased involvement in collaborations in 2013.

U.S. ICT firms are fairly confident in their overall competitiveness heading into 2013. While 35% expect increasing globalization to affect their R&D efforts and 58% feel there is some risk in the U.S. losing technological leadership in ICT, only 5% feel this risk is significant.

Industry Perspectives



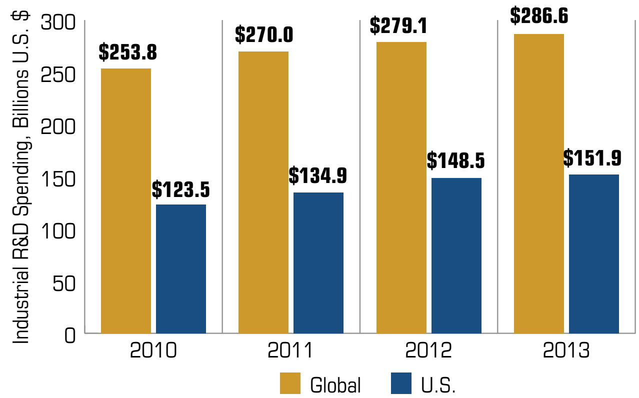
Source: Battelle, *R&D Magazine*

U.S. and Global Industry Forecast

Even with increasing Asian ICT R&D levels, the U.S. still accounts for more than half of global ICT R&D and nearly all of the global 2011 to 2012 growth. ICT industry performance is strongly correlated with economic conditions in the U.S. and abroad.

Uncertainty regarding 2013 will likely have a dampening effect on U.S. and global ICT industry R&D growth. Most of the forecast 2012 to 2013 U.S. growth rate of 2.3% will come from the largest firms, as smaller firms remain uneasy in the current economic environment. Globally, the industry will have a slightly higher growth rate of 2.7%, representing improving R&D investment conditions for Asian and European ICT firms. Returning to historical high R&D growth rates within ICT will depend on the ability of emerging ICT firms to replicate both the size and growth rates of some of the newer ICT firms, such as Google. Firms such as Huawei Technologies and Facebook may indeed reach these levels.

Information/Communication Technologies



Source: Battelle/*R&D Magazine* estimates and forecast

Developing Next-Generation Hardware

ICT depends on integrated circuits (ICs) and embedded software control systems. The primary IC in an ICT hardware system or device is the central processing unit (CPU), which today consists of multiple cores on one integrated device. The scale of the features on these multicore CPUs continues to shrink according to Moore's Law down to the low nanometer scale. Efficiently fabricating multicore devices with nanoscale features requires extremely sophisticated processes.

These devices are fabricated on silicon wafers that are 150, 200, and 300 mm in diameter in tightly controlled manufacturing facilities, or fabs, that generally cost $1 to $3 billion to build and run continuously. Currently there are about 160 fabs in the world for manufacturing devices on 150-mm wafers, 150 fabs for 200-mm wafers, and 80 fabs for 300-mm wafers. For increasing the economies of scale (building more devices on one silicon wafer) engineers and scientists are currently developing the next generation of processing hardware for the 450-mm wafer.

The Global 450 Consortium is a $4.8 billion collaboration in the Albany (N.Y.) NanoTech complex that's backed by Intel, IBM, Globalfoundries, Samsung Electronics, and Taiwan Semiconductor Manufacturing (TSMC). Widespread adoption of 450-mm wafers is not expected until 2018 at the earliest and more likely 2020. The first alpha development tools will not be available until early 2013 with the first production tools expected in 2017. The transition from 200- to 300-mm wafers occurred in the early 2000s, but the complexity and uncertainty of the 300- to 450-mm transition is taxing even the most technologically savvy corporations in the world.

Most estimates of the development costs for creating the production tools and processes for 450-mm wafers is about $17 billion cumulatively, with about $2 billion being spent in 2012. Other estimates for the development costs go as high as $40 billion.

The developers state that the transition to 450-mm is inevitable and predict that the top 10 wafer fab equipment suppliers will contribute about 80% of the R&D required to support the transition.

Basic Research Gaps

The evolution from 300-mm to 450-mm wafers is strictly a development program, which is funded primarily by companies anticipating future profits. However, analysts are now talking about a gap in basic information and communication technology research in the U.S. due to reduced federal government funding capacity. A white paper by the Telecommunications Industry Association (TIA) states that if this gap is not remedied, "U.S. leadership and innovation in the ICT sector is threatened, with consequences for the U.S. economy and national security." Over the past 35 years, the U.S. federal government has been the primary sponsor of basic research, especially in ICT, as all but a few corporate R&D laboratories no longer were able to afford the high costs and risks of basic research. Their corporate mandates required shorter-term R&D with faster paybacks.

The National Academy of Sciences (NAS) agrees that federal long-term basic research aimed at fundamental breakthroughs has declined in favor of shorter-term, incremental, and evolutionary products whose main purpose is to enable improvements in existing products and services. The TIA expresses concern that the U.S. is beginning to cede leadership in ICT. The U.S. has fallen to eighth place among OECD (Organization for Economic Cooperation and Development) countries in R&D intensity, there are fewer U.S.-based firms in the top 250 ICT firms than in previous years. While revenue growth for U.S. ICT companies increased by 70% from 2000 to 2009, it increased in other countries more dramatically—China (315%), Finland (101%), Germany (90%), India (473%), Singapore (135%), South Korea (136%), and Taiwan (428%). These other countries are directly benefitting from government policies aimed specifically at growing their ICT sectors and attracting research investments.

Industrial R&D—Aerospace/Defense/Security

Overview

Cost containment will influence aerospace, defense, and security (ADS) R&D, where industry investment is linked to government needs and funding. In the west, large new weapon system development programs will continue to give way to technologies that extend the life of extant platforms. In space-related research, budget constraints at NASA may stimulate additional new private sector investment in the U.S. and abroad. In civil aviation, China's ambitions to penetrate the world market will depend on their ability to deliver lower procurement and operating costs from airliners now in development.

Cybersecurity continues to be a leading area for rapid cycles of defense R&D and deployment. Autonomous systems, advanced data analytics, and critical infrastructure protection will also remain research priorities with common reliance on advancements in information and cyber technologies.

The U.S. Department of Defense also creates market pull for technology in non-defense domains. As one of the world's largest energy users, DOD mission needs drive sustainable energy deployments in renewable fuels, installation-scale smart electricity grids, and portable power for the warfighter.

Leading U.S. R&D Firms

Though R&D at a number of firms has been affected by divestitures or acquisitions, the top ten ADS R&D spenders remain the same as last year. Once again, Boeing leads the segment in R&D spending by a wide margin, but it is on pace to invest nearly $500 million less in 2012 than it did in 2011. Perhaps this could be attributed to a post-Dreamliner launch, revised level of base R&D activities. Our estimates for most of the leading aerospace/defense/security companies, however, show 2012 R&D investments are likely to be below 2011 levels. This common theme indicates that real R&D budget reductions are being enacted by the segment's firms as a result of continued cuts in federal defense spending.

Of the leading ADS industry R&D performers, only Raytheon and Lockheed Martin are projected to have higher 2012 R&D expenditures. Beyond the top ten, a number of key technology firms such as L-3 Communications, BE Aerospace, Esterline Technologies, and Orbital Sciences are also likely to exceed their 2011 R&D levels.

Aerospace/Defense/ Security	2010	2011	Q1-Q3 2012
Top U.S. R&D Expenditures	Millions, U.S. $		
Boeing	4,121	3,918	2,545
UTC - Aviation (e)	811	1,096	723
GE - Aviation (e)	684	918	638
Raytheon	625	625	543
Lockheed Martin	639	585	456
Honeywell - Aerospace	479	565	424
Northrop Grumman	580	543	386
Textron	403	525	374
General Dynamics	325	372	251
Rockwell Collins	348	346	240

Source: Battelle/*R&D Magazine* and Current Company Information; (e) = estimated

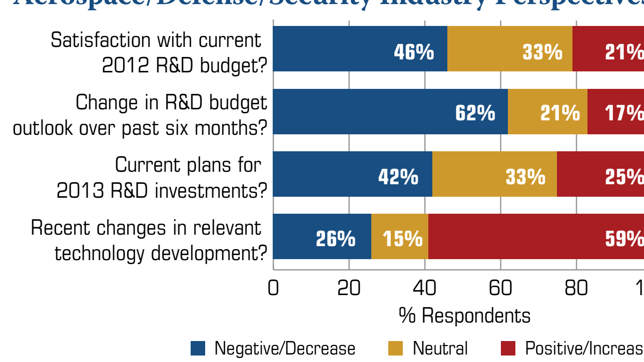
U.S. Industry Perspectives

Many aerospace/defense/security industry survey respondents reported a negative perspective on their 2012 R&D budgets, reflecting concerns over reduced defense spending. Nearly half (46%) of the respondents were concerned that their 2012 budgets were too low, and 62% have become even more pessimistic in their outlook for 2013.

This concern is manifested in 2013 R&D spending plans as 42% of the respondents state that their 2013 budgets will be decreasing over 2012. Only 25% of the ADS respondents expect their 2013 budgets to increase, the smallest share among the industry segments we examine. Overall, the industry is working to get the most value out of limited funding with 79% of the respondents seeing even tighter budgeting requirements this year than last.

Though R&D spending may be declining, industry respondents are still positive about the level of current U.S. technology development. Their views of the future are not as positive, however. More than three quarters (77%) perceive the U.S. is at some risk of losing significant technological leadership in the next three years—33% feel this risk is significant.

Aerospace/Defense/Security Industry Perspectives



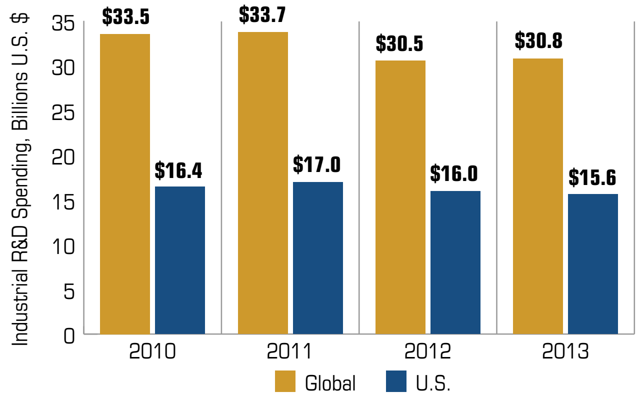
Source: Battelle, *R&D Magazine*

U.S. and Global Industry Forecast

These aerospace/defense/security industry R&D spending levels are forecast in terms of the internal resources that firms will invest. These values, to the extent possible with reported data, exclude the value of government contracted research. Significant cuts to contract R&D, related to federal budget reduction, do affect the level and priority of internal investments. Reductions in overall sales to government agencies further limit the internal resources available for R&D.

These continued reductions in federal defense spending, in conjunction with industry acquisitions and related R&D rationalization (such as UTC's purchase of Goodrich), may continue to restrain U.S. ADS R&D. We forecast a 2.0% decline from 2012 falling to $15.6 billion in 2013. Globally, we forecast a net 0.9% increase as China and other emerging markets increase their investments in both civil aviation and defense-related technologies.

Aerospace/Defense/Security



Source: Battelle/*R&D Magazine* estimates and forecast

Cost Pressures Influence R&D

Spiraling development costs are limiting the number of new platform systems in western defense budgets, while creating new opportunities to develop technologies for platform and service life extension. For example, advanced sensors will enable condition-based maintenance to increase efficiency, while next-generation avionics will further extend aging aircraft like the B-52.

High development and procurement costs may threaten the preservation of industry's long-term R&D capacity. For example, when the F-35 development program is complete, for the first time in U.S. aviation history, no next-generation fighter is projected to be in development. The European defense establishment faces similar circumstances.

While in the midst of a rearmament program, Russia also continues to reduce R&D as a percentage of procurement. Nevertheless, Russia recently affirmed commitment to technological advancement by forming the DARPA-like "Foundation for Advanced Research Projects in the Defense Industry" to fund areas like unmanned aerial vehicles, new materials, advanced electronics, and hypersonic systems.

Trends and funding outlook for China's defense R&D are difficult to determine. Some have estimated expenditures of US$ 5 to 10 billon, including major programs aimed at technological parity like the J-20 fighter. In civil aerospace the Commercial Aircraft Corporation of China is developing a new narrowbody aircraft to compete with Boeing and EADS by 2016.

In 2012, shuttle retirement and cost pressures at NASA drove a historic shift toward commercial space flight. NASA and other federal government space-related budgets will remain constrained, but a corresponding increase in private-sector development will continue.

Interconnected Technology Development & Deployment

Advancements in intelligence, surveillance, and reconnaissance (ISR) systems are among the most urgent global needs for homeland security, threat anticipation, and support of asymmetric warfare operations. ISR also illustrates the need for parallel development of synergistic technologies to achieve the mission.

Air- and sea-based unmanned systems have been deployed in unprecedented levels by the United States. Other nations are investing in similar development programs, such as China's "Pterodactyl" drone. Improved autonomous operation will be an ongoing research objective for these platforms, along with stealth, endurance, reliability, and lower cost. As part of a growing network of constant-surveillance assets, sensor systems in domains like border and maritime security, and other diverse information sources, ISR technologies contribute to large datasets that must be mined using big data analytics. Like the big data challenge in life science, exploitation of such ISR data depends on rapid progress in information processing research.

At each step, ISR systems and data are exposed to cybersecurity threats, for which R&D funding will continue to be prioritized. DARPA, DHS, and the private sector see pervasive vulnerability and a need for a fundamentally new approach to make transformative advancements in areas like reusable high-assurance components, greater automation of detection and response, and more secure cyber-physical interfaces. Another critical issue is cyber exploits which arrive in the technology supply chain, e.g., compromised FPGA's and ASICs from Asia—a problem that likely can't be solved either by secure domestic production or by component testing.

ISR assets are not the only exposure. As U.S. Secretary of Defense Panetta recently warned of the cyber threat to America's critical infrastructure networks: "They are targeting the computer control systems that operate chemical, electricity and water plants and those that guide transportation throughout this country." Technology developments to defend and harden these key national resources will likely remain a priority in 2013 and beyond.

Industrial R&D—Energy

Overview

Private-sector energy R&D covers a diverse portfolio of technologies related to electricity generation and use, exploration and extraction, efficiency, clean and sustainable fuels, and transportation. Energy innovation can be influenced by public-sector policies, research, and funding which complements and stimulates industrial R&D. This cooperation is important due to infrastructure and capital costs for deployment, public and economic interests related to energy, and the ability of governments to support long-range research.

Technology developments and economic growth also influence R&D priorities. Over the last year, revised estimates of "technically accessible" natural gas and oil reserves in North America have rapidly reshaped the global energy landscape. In addition, growth in China, India, and the Middle East will increase energy demand in absolute and as a portion of the global total. This shift creates opportunity for innovation.

Leading U.S. R&D Firms

Economic, investment, technical changes caused some changes in the top ten list of energy R&D spenders for 2012. Most notable is the absence of battery technology firm A123, which entered bankruptcy this year after investing $77 million in 2011 and $45 million through the first two quarters of 2012. Another change involves our decision to remove Cree from the list of energy R&D firms to focus the list more on energy generation and related technologies.

General Electric (GE) continues to invest more in energy technology R&D than any other firm. Though embedded within overall R&D reporting, our 2011 estimate places GE's energy-related R&D at more than twice the next largest R&D performer, Exxon Mobil. Based upon R&D/sales ratios, GE's 2012 energy R&D is expected to decline slightly from 2011 levels. Overall, most firms with end 2012 with R&D investment levels within $1-3 million above or below their 2011 levels. USEC is a significant exception to this investment trajectory. Through three quarters USEC has already surpassed its 2011 total by $41 million.

Energy	2010	2011	Q1-Q3 2012
Top U.S. R&D Expenditures	Millions, U.S. $		
GE - Energy Infrastructure (e)	1,457	2,126	1,478
Exxon Mobil	1,012	1,044	788
Chevron	526	627	448
ConocoPhillips/Phillips66 (e)	230	267	202
Itron	139	163	134
First Solar	95	141	101
USEC	110	127	168
Babcock & Wilcox	69	106	91
Advanced Energy Industries	57	65	44
SunPower	49	58	46

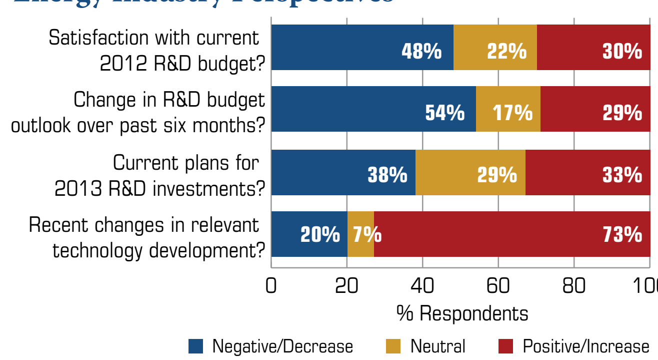
Source: Battelle/*R&D Magazine* and Current Company Information; (e) = estimated

U.S. Industry Perspectives

More than any other segment, 48% of the energy and related technology respondents were concerned with the size of their 2012 budget. Much of this concern stems from 2012 budgets failing to reach the levels of strong 2010 and 2011 budgets. Concerns over R&D budgets within the energy technology industry look to continue, with more than half (54%) of the respondents becoming more pessimistic over the last six months. This concern, thus far, is only partly represented in the current plans for 2013. While 38% of the respondents expect reduced 2013 R&D budgets, another 33% expect increases, and 29% expect no change in their budget over last year. These concerns and negative outlooks may more reflect the respondents' original hopes for better 2013 budgets. Now, due to variety of factors these budgets are likely to be closer to 2012 budgets than 2011 budgets.

Energy technology respondents are extremely positive with regard to technology development. Fully 73% report positive technological gains have been made in the last year and that strong potential exists to increase the level of energy technology innovation in the U.S. They also express strong concerns that increasing globalization may cause the benefits of these gains to bypass the U.S., with 83% of respondents seeing the U.S. at risk of losing technological leadership in its key energy technologies in the next three years.

Energy Industry Perspectives

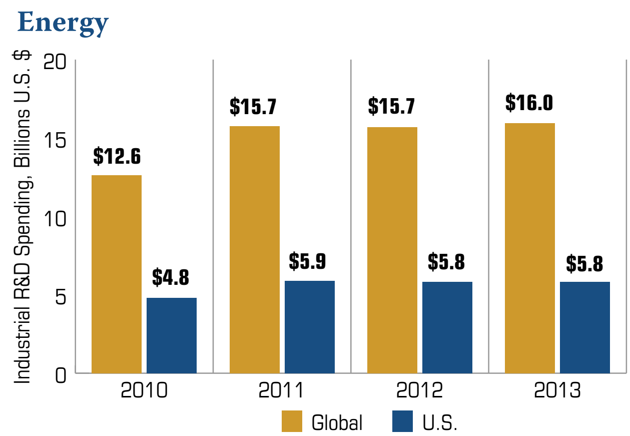


Source: Battelle, *R&D Magazine*

U.S. and Global Industry Forecast

The energy segment will experience limited increases in R&D over the next year. As market demand and economic conditions continue to dampen sales for many renewable energy technology firms, R&D growth rates will continue to be flat. Brighter prospects may come from the major petroleum and natural gas producers.

U.S. energy industry R&D investment is concentrated in a small number of firms, with the top 10 firms accounting for 80% of all R&D. The generally flat growth of these firms combined with $100 million in annual R&D eliminated through industry bankruptcies since the end of 2011, leads to a slight 0.2% increase in U.S. energy industry R&D in 2013, reaching $5.83 billion. Depending on the extension of various research and production tax credits, even this level of growth may not be attainable. Globally, the situation is somewhat better with energy industry R&D reaching $15.95 billion in 2013, up 1.6%. from 2012.



Source: Battelle/*R&D Magazine* estimates and forecast

Market Transformations Influence R&D Priorities

New estimates of U.S. conventional and unconventional reserves are large enough that the International Energy Agency projects the U.S.—consumer of 18% of the world's energy—will be energy self-sufficient within a decade and will overtake Saudi Arabia and Russia as the largest producer of oil and natural gas.

Accessibility of shale gas, tight oil, and other unconventional reserves is the result of decades of public and private technological progress in drilling, fracturing, and geologic characterization. The largest points of energy consumption or conversion in the U.S. economy—electricity generation, industrial processes, and transportation—will all be affected. For example, shale gas could influence planned replacement of hundreds of megawatts of generating capacity due to low capital cost versus coal and nuclear, moderate carbon profile, and abundant supply that should keep marginal fuel costs low.

Implications for future R&D funding priorities can be inferred. Industry-driven applied research and engineering will increase productivity and lower the cost of unconventional hydrocarbon extraction. Additional advancement is needed in water technologies, fracturing media, geo-characterization, environmental assessment, and down-hole materials and sensors. Even cleantech innovation contributes: carbon management R&D now involves synergistic applications like enhanced oil recovery.

A smaller but important market transformation is also occurring in nuclear energy as demand for plant construction rises in China and the Middle East, while other countries want new safety technologies or reduced dependence on nuclear power after Fukushima.

Shifting Momentum in Cleantech

Emerging clean energy technologies often require public-sector support to reach commercial viability. In the U.S., resources have been constrained by the wind-down of ARRA funding and by economic conditions overshadowing policy on climate change. However, other countries continue to mandate greater sustainability and efficiency, which will drive innovation. In addition, some technologies are gaining momentum in the private sector based on market demand.

Biofuels and related bio-based chemicals are a good example. Although bio-ethanol deployment faces competition with food markets, R&D on cellulosic feedstocks is promising, having achieved progress that justifies scaled-up development. Blendable fuels from thermochemical technologies are also coming closer to commercialization.

Grid-related R&D is also advancing with a mix of public and private support. Connection of intermittent renewables and vehicles to the electricity grid will continue to drive government support for R&D in grid-scale storage and energy systems integration. Commercial deployment of demand-side management technology like smart meters continues, while improved reliability and security will likely be the emphasis of industry-sponsored R&D and capital investment.

Conversely, the near-term solar R&D outlook is weak. While technological progress in efficiency and cost has continued, global over-supply of photovoltaics from China has led to a sharp reduction in investment. Government programs like SunShot will continue, as will deployments of both photovoltaic and concentrated solar power systems, but recovery of private sector innovation will take several years.

Similarly, transportation electrification has lagged expectations. Limited electric vehicle sales are attributed to insufficient range, high cost, and long charging time using current technology, and the slow market contributed to recent bankruptcies of several high-profile battery technology companies.

More broadly, China's proactive energy policy combined with the scale of its economy and infrastructure development will propel global clean energy research. Energy intensive industries are main drivers of China's growth in energy consumption, so the current Five Year Plan calls for lower industrial and per-capita energy use while increasing availability of clean energy.

Industrial R&D—Chemicals & Advanced Materials

Overview

Chemicals and advanced materials comprise a broad sector that includes chemicals, catalysts, polymers, metals, ceramics, and nanomaterials—from products sold by the trainload to those that cost hundreds of dollars per gram. It is an innovation-intensive business: for example, the U.S. chemical industry is responsible for over one tenth of all patents filed in the United States. The industry also has a large economic impact in employment and international trade.

There is a ripple effect as new materials catalyze applications research in other markets like transportation, pharmaceuticals, and energy. For example, progress in battery-based energy storage depends largely on performance improvements in component materials. At the same time, major chemical and metal producers are themselves major consumers of energy and materials, which can create market pull for deployment of new technologies.

R&D activity involves either new production processes or new forms and compositions of matter. *De novo* and computational design are increasingly common in early stages of advanced materials research. Research objectives can include sales growth from development of higher-performing products, cost reductions through yield improvement, sustainability for cost or customer reasons, and regulatory compliance. Some large companies may undertake R&D or make venture investments and acquisitions in order to forward integrate into value-added products which are based on advanced materials.

Leading U.S. R&D Firms

This examination reflects our segment interest in chemicals, composites, coatings, non-ferrous metals, and other advanced materials. With its 2011 R&D budget growth, DuPont becomes the largest materials R&D spending firm in the U.S. Most of the top ten leading U.S. chemical and advanced materials firms continued to increase their annual investments in R&D, with all except Huntsman on pace to exceed 2011 levels in 2012. These growth rates could range from less than 1.0% in the case of Dow Chemical to 15% or more for Goodyear and Eastman (as it fully integrates the former Solutia R&D portfolio), with most firms' R&D spending growth rates at least outpacing inflation.

Beyond the top ten, Ashland appears to be pursuing a significant increase in its R&D efforts to build its specialty ingredients portfolio. Through the first three quarters of 2012, it has already exceeded its 2011 totals by nearly $10 million. At this pace it could potentially invest 40% more in 2012 than it did in 2011. If Ashland indeed achieves this growth, they will likely enter the top ten list in next year's forecast.

Chemicals & Advanced Materials	2010	2011	Q1-Q3 2012
Top U.S. R&D Expenditures	Millions, U.S. $		
DuPont	1,651	1,956	1,539
Dow Chemical	1,660	1,646	1,245
3M Co.	1,434	1,570	1,216
PPG Industries	394	430	337
Goodyear Tire & Rubber	342	369	274
Honeywell - Adv. Materials (e)	212	279	218
ALCOA	174	184	141
Huntsman International LLC	151	166	112
Eastman Chemical Co.	145	158	136
Air Products & Chemicals	117	118	98

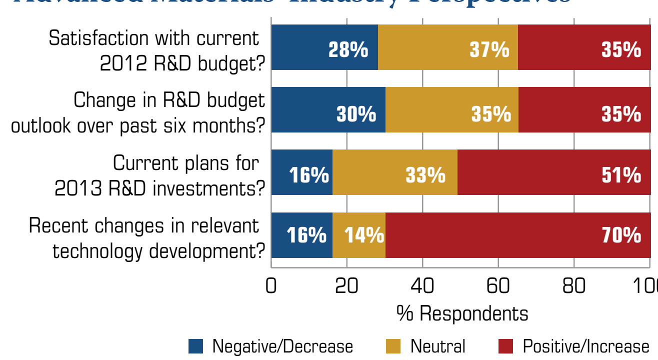
Source: Battelle/*R&D Magazine* and Current Company Information; (e) = estimated

U.S. Industry Perspectives

The U.S. chemicals and advanced materials industry respondents are guardedly optimistic in their view of the segment's R&D future. Only 28% of the respondents reported a negative view of their 2012 budget, with 35% having a positive view. Overall outlook is also improving with 35% of the respondents having grown more positive (the second highest among our segments), while only 30% expressed a more negative outlook (the lowest share among our segments). More than half of the respondents expressed optimism that their R&D budgets would be increasing for 2013, although most respondents expect their budget increases to be very small.

Globalization is the watchword for the U.S. materials industry, as most U.S. firms have had significant market success in existing and emerging global markets—41% of the respondents report their firm's globalization efforts have affected R&D operations. With this globalization, 63% of the respondents believe U.S. competitiveness is at risk.

Advanced Materials Industry Perspectives



Source: Battelle, *R&D Magazine*

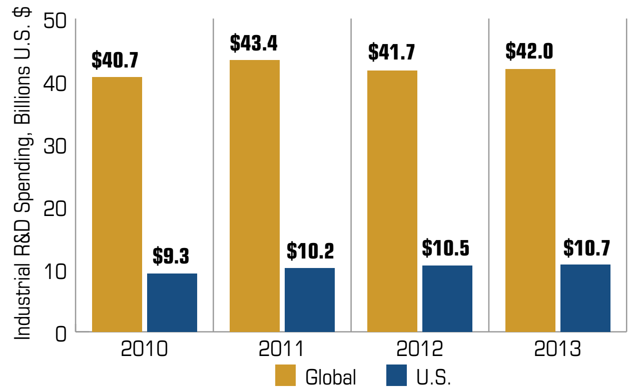
U.S. and Global Industry Forecast

The forecast for the U.S. chemicals and advanced materials industry takes into consideration the generally positive outlook among our respondents and the uncertainty facing the U.S. and global economies heading into 2013. As a key supplier industry to all four of our other segments, the outlook for chemical and materials R&D is strongly tied to these and other markets.

U.S. R&D is forecast to increase within this segment by 1.6% over 2012, lower than the 1.9% expected rate of inflation. Many smaller specialty materials firms will likely keep pace with inflation or slightly better, but some of the larger multi-national firms will be more inclined to keep their R&D investments in check until the global economy exhibits a stronger recovery.

Globally, the overall growth in R&D budgets is even lower, forecast to grow by only 0.6% to just under $42.0 billion in 2013. Much of this growth will occur via U.S. firms' global joint ventures.

Chemicals & Advanced Materials



Source: Battelle/*R&D Magazine* estimates and forecast

Materials Innovation Enables Research in Other Sectors

Among many markets that depend on materials innovation, energy R&D is a good illustration that also involves numerous technology thrusts. Often, a target for performance or cost is known, and materials development is a critical path to achieve it. All of the following energy-related chemistry and materials science examples are expected to continue receiving research attention in 2013.

Metal-organic frameworks (MOFs) represent a platform with multiple applications. Recent breakthroughs have demonstrated utility for hydrogen and CO_2 storage, catalysis, and even sequestration of radioactive iodine gas released from spent nuclear fuel. Through R&D on the structural elements of MOF's, performance can be tuned for each purpose.

Sustainability is often an objective of materials R&D, typically seeking to replace a material in commerce. Examples include developing replacements for embargoed rare earths used in the magnets of electric vehicle motors, and transforming renewable lignin into low-cost carbon fiber for lightweighting and other applications.

Renewable energy and carbon-free transportation relies on battery materials research. For example, the boundaries of scale and safety of lithium ion batteries are continually expanded by advances in electrolyte and electron shuttle chemicals and anode/cathode materials.

Finally, one of the most exotic technologies that will be enabled by materials innovation is "fuel from sunlight." ARPA-e sponsors extramural R&D into processes and materials which can split water to make hydrogen or reduce carbon dioxide to make sugar. This grand-challenge research seeks to replicate one of the most prevalent chemical processes on Earth: photosynthesis.

Creating A Global Materials Network

The Dow Chemical Company, with corporate headquarters in Midland, Mich., recently announced the opening of its Dow Seoul Technology Center, a global R&D center with a focus on technological advances in display technologies and semiconductor-related applications. The new R&D center is strategically located for serving its semiconductor and display materials customers. With the addition of this center, Dow has invested more than $400 million in South Korea over the past decade to establish advanced manufacturing sites for semiconductor, display and LED technologies. The center's research focus areas include lithography, organic light-emitting diodes (OLEDs), display materials, and advanced semiconductor chip packaging.

About a year ago, General Motors China opened its Advanced Materials Lab in Shangahi. Part of GM China's Advanced Technical Center, researchers at the new materials lab work on cutting-edge research for new battery technologies and lightweight automotive materials. This includes the development of innovative technologies for battery cell design and fabrication and the validation of advanced cell materials provided by suppliers. Their goal is to integrate the new battery cells into future battery systems for GM vehicles. Their focus is on the development of lithium-ion battery technologies through enhanced cell chemistry, cell and pack design and optimization of the battery's thermal management system. The ultimate goal is to make the battery systems smaller, lighter, and less costly than current lithium-ion systems.

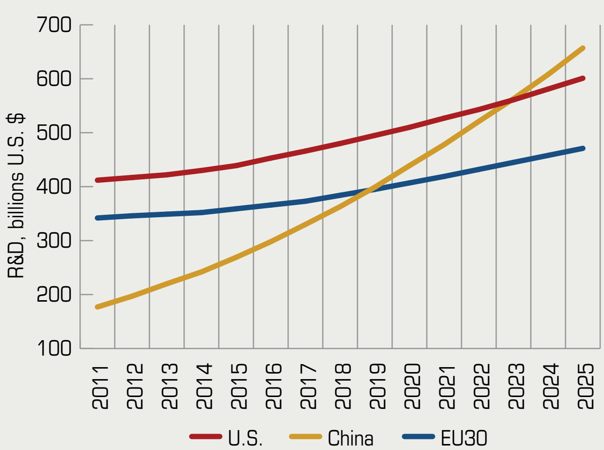
BASF recently opened a production facility in Elyria, Ohio, for fabricating nickel-metal-cobalt cathode materials for lithium-ion batteries used in electric vehicles and hybrids. The new materials plant was built with $25 million in federal stimulus grants. The process for producing this material was initially developed at Argonne National Laboratory, Illinois, which BASF researchers at their Beachwood (Ohio) lab scaled up to a viable production process. The BASF researchers said that the Argonne process should be able to eliminate one of the two chemicals now being used in large lithium batteries by making the cathodes entirely out of nickel-manganese-cobalt instead of a blend of that material and another manganese combination. This also should enable the batteries to hold more power and be more durable.

The Internationalization of R&D

R&D investments have become highly competitive between nations, with each looking to outspend the others to maintain a competitive edge. This internationalization of R&D now pits the U.S., China, Japan, and the EU against each other to develop breakthrough technologies that can be developed into marketable products that can build their country's export trade. Each of these countries has different strengths and capabilities and each is modifying their science and technology (S&T) policies to obtain the most cost-effective and productive means for enhancing R&D staffs and resources.

For the past half century, the U.S. has dominated global R&D spending with increasingly large industrial and government funding matched with research performed in leading corporate, government, and academic laboratories. Over the past ten years, other nations have implemented policies and investments to increase the long-term benefits of strong R&D programs. These emerging economies have developed strong R&D programs that now are challenging the U.S. dominance in a number of specific areas. China in particular, for the past 15 years, has steadily and consistently leveraged its positive balance of trade to increase R&D as a percent of GDP. China's economy is already set to surpass that of the U.S. within the next three years, and its R&D investments will do the same in less than 10 years.

U.S. - China - EU Annual R&D Spending



Source: Battelle/*R&D Magazine*

Growth in R&D investments in emerging economies are compared to the leadership of U.S. spending, but that leadership has eroded over the past several years due to efforts to constrain high U.S. debts. The amount of money spent on U.S. R&D is still substantial (more than $400 billion), but in real dollar value it has continued to decrease over the past several years. Current indications suggest that this trend is likely to continue through the remainder of this decade.

BRIC Growth Changes Landscape

As noted, massive deficit spending in the U.S. already limits the ability of the U.S. to match China's R&D investment growth, with the result being that new technologies are likely to be discovered and marketed sooner by China, further increasing the economic disparity that's likely to occur over the next several years. China belongs to a group of countries referred to as BRIC (an acronym for Brazil, Russia, India, and China), which are all deemed to be at similar stages of advanced economic development. Formally established in 2006, BRIC has come into popular use for its discrimination from the G7 economies (consisting of the U.S., France, Germany, Japan, Italy, U.K., and Canada, whose finance ministers meet on a regular basis to discuss economic policies—G7 countries account for roughly half of the world's total GDP).

BRIC countries account for roughly half of the world's population and a combined GDP that roughly matches that of the U.S. South Africa applied for and became a full member of the BRIC organization in 2011. While not a formal trading organization, the BRIC members use their political alliance as a way to influence the U.S. position on major trade accords or to influence political concessions, such as proposed nuclear cooperation with other countries.

Europe's Sustained Commitment

Europe is the third player in the global R&D environment with about a quarter of the world's overall R&D spending. European R&D is spread throughout 34 countries, most of which are members in the European Union (EU)—half of the Top 40 R&D spending countries (page 5) are in Europe. Like the U.S., this region is also struggling with massive debt loads that have affected its ability to maintain somewhat lofty long-term R&D investment goals. Despite the setbacks that threaten the economic stability of individual European countries and the EU organization, the countries continue to invest in R&D through their own political structures and collectively in a series of EU S&T programs, such as the Framework Programme (FP). Started in 1984, the FPs have been quite successful and continue to see substantial support in each iteration, which will enter the 8th version at the end of 2013.

The Energy Factor

The power shifts that are expected in R&D investments and GDP growth means that India and China combined will outspend the combined R&D budgets of the U.S. and Europe by 2025. By 2050, China's GDP is expected to be roughly twice that of the U.S. and India will match the U.S. GDP of roughly $38 trillion. The wild card in these forecasts is the recent shift in energy production. According to the IEA (International Energy Association), oil shale production in the U.S. is expected to make the U.S. energy independent by 2020, with significant positive changes in trade balances as a result. China, on the other hand (and likely India as well), are expected to increase their oil energy imports to satisfy the energy demands from their growing economies and already massive, increasing populations.

R&D into alternative energy sources will offset some of this demand, as will the development of more energy-efficient technologies. However, the high energy densities, efficiencies, and massive existing infrastructure of petroleum-based products will likely maintain fossil fuels as the energy source of choice for many decades into the future.

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2013 Global *R&D Funding Forecast*

BRIC — Brazil

While strictly categorized as an emerging nation by the IMF, the Federative Republic of Brazil is the world's fifth largest country in geographic size and population and sixth overall in gross domestic product (GDP). By 2040, Brazil's economy is forecast to be the fourth largest in the world, behind China, the U.S., and India. Brazil dominates South America in terms of its economy, vast mostly untapped natural resources, large labor pool, and R&D spending. According to our R&D Funding Forecast, Brazil's R&D spending is expected to increase in 2013 to $31.9 billion, an 8.1% increase over the $29.5 billion it spent in 2012. This increases its share of global spending from 2.0% to 2.1% and ranks it tenth globally, slightly ahead of Canada. Brazil's R&D spending also accounts for more than 75% of the total R&D spent in all of South America. These statistics reflect

2013 GDP, billion US$, PPP	$2,453
2013 GERD, billion US$, PPP	$31.9
R&D/GDP	1.30%
Population, million	199.3
GERD/Person	$160
Published Research Papers	
1999-2003, Physics	8,600
2004-2008, Physics	10,100
1999-2003, Chemistry	3,200
2004-2008, Chemistry	5,200
Academic Research Share	29%
Institute Research Share	28%
Industry Research Share	44%

Source: Battelle/*R&D Magazine*, UNESCO, Thompson Reuters

trends in Brazil's R&D investments over the past decade when the intensity of its R&D increased by 10% from 0.98% to 1.09% of GDP between 2002 and 2008, while its economy was growing by 27%, thereby increasing net R&D spending by 35% during that period. The global recession slowed this growth slightly in 2009 and 2010, but Brazil was one of the first countries to recover in both its economic growth and R&D spending.

Brazil's science and technology output mirrors its overall global R&D ranking, with an average of more than 2% of the world output across ten fields of science tabulated by Thomson Reuters. The country has strengths in the life sciences, particularly those related to its natural resources, such as tropical medicine (18% share of world technical publications), entomology (7% share), biology (6.4% share), and zoology (5.6% share).

Collaborative Focus

Brazilian researchers collaborate primarily with U.S. and leading western European researchers. Leading international collaborators including the University of Texas, Harvard University, University Paris 06, Centre Nationale de la Recherche Scientifique (France), and McGill University (Canada).

Brazil's Industrial R&D

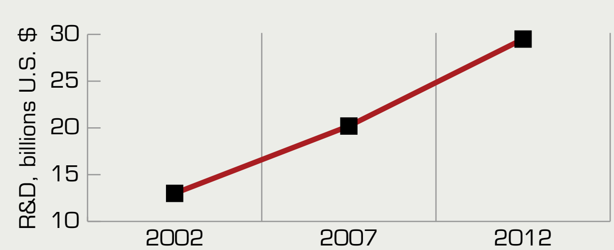
	2010 R&D mil. U.S. $	R&D, % Revenue
Petroleo Brasiliero	943.9	0.80%
Vale	834.6	1.90%
Gerdau	122.9	0.70%
CPFL Energia	102.5	1.50%
TOTVS	85.9	13.30%
Embraer	68.5	1.30%
Randon SA	59.4	2.80%
WEG	57.7	2.30%
Braskem	45.1	0.30%

Source: Battelle/*R&D Magazine*, EU Industrial R&D Scoreboard

Industrial research accounts for the largest share (44%) of Brazil's total R&D budget. Embraer is the largest aerospace firm in Brazil and the third largest commercial aircraft maker in the world, behind Airbus and Boeing. With a relatively modest R&D budget—by global standards—of about $70 million, Embraer is developing both new commercial and regional military aircraft (tankers and fighters). Due to high labor costs, few aerospace investors have established a foothold in Brazil in the past, however GE Aviation is now developing engines in Brazil for Embraer and Boeing is considering manufacturing and research collaborations with Embraer.

TOTVS, the largest software company in Latin America (the sixth largest worldwide) with more than half the market in Brazil and more than a third of the market elsewhere, recently announced that TOTVS Labs has opened a new R&D facility in Mountain View, Calif., to create products for cloud computing, social media, big data, and mobile applications. It hopes to develop strategic partnerships with technology vendors in the Silicon Valley area who are interested in expanding into Latin America. TOTVS says that it is focused on stealth R&D projects aimed at bringing products to market that fuel innovation and achieve scale with a global reach.

Brazil's R&D Spending Growth



Source: Battelle/*R&D Magazine*

Gross domestic expenditures on R&D (GERD) in the Russian Federation nearly doubled (at constant prices) from 1998 to 2008, one of the highest growth rates at that time. Russia's 2013 R&D is forecast to grow to $38.5 billion, a 4.0% increase over the $37 billion spent in 2012. Russia is the largest country in the world in terms of size, but it is unfavorably located in relation to sea lanes and lacks proper soils and climates for agriculture. According to the International Monetary Fund (IMF), its economy is expected to see moderate growth (3.8%) over the next several years, buoyed in part by its energy exports to Europe.

Unfortunately, Russia is plagued with a number of structural and economic imbalances that hinder the effectiveness of its R&D investments. While Russian researcher salaries are higher than those for the general Russian commercial and manufacturing sectors, they are just a fraction of those offered for similar positions in the U.S., Germany, South Korea, and other western countries. As a result of this, corruption allegations, and Vladimir Putin's 13 years of a semi-authoritarian political system, up to a quarter of Russia's well-educated young people have stated that they are considering emigrating to more attractive countries, according to a recent report on National Public Radio (NPR). Those considering emigration cite concerns for their children obtaining sub-par education in Russia, and few expect the political situation in Russia to change any time soon.

2013 GDP, billion US$, PPP	$2,598
2013 GERD, billion US$, PPP	$38.50
R&D/GDP	1.48%
Population, million	142.5
GERD/Person	$270
Published Research Papers	
1999-2003, Physics	37,800
2004-2008, Physics	34,500
1999-2003, Chemistry	29,500
2004-2008, Chemistry	28,600
Research Institute Share	52%
Design/Industry Research Share	17%
Academic Research Share	14%
Other Research Share	16%

Source: Battelle/*R&D Magazine,* UNESCO, Thompson Reuters

Research Equipment Concerns

Additionally, existing research equipment, machinery, and facilities have not been upgraded. According to the latest UNESCO (United Nations Educational, Scientific and Cultural Organization) *Science Report*, a quarter of the machinery and equipment used for R&D in Russia is more than 10 years old and 12.3% is more than 20 years old. The degree of wear and tear on this equipment has been calculated at 55% and installations specifically designed for R&D are available at less than 7% of the R&D organizations and less than 20% of them have their own experimental base. For the former USSR (which had a 1990 R&D budget that was more than twice the current Russian R&D budget), this experimental base was 34%.

Russia's Industrial R&D

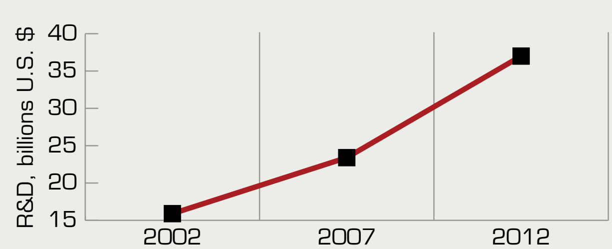
	2010 R&D mil. U.S. $	R&D, % Revenue
Gazprom	752.3	0.70%
Lukoil	114.1	0.10%
AvtoVAZ	73.1	2.40%

Source: Battelle/*R&D Magazine,* EU Industrial R&D Scoreboard

Russian military-based R&D spending, considered at one time to be nearly equal to that of the U.S., has been reduced from 38% of the total R&D budget in 2005 to just 18% in 2012, according to a recent report by RIA Novosti, the Russian International News Agency. Vladimir Pospelov, a member of Russia's Military-Industrial Commission, stated that the cuts have hampered the implementation of mid- and long-term R&D projects. A large number of R&D projects have already been terminated since 2009 as they became obsolete, resulting in large (~$86 million) termination costs. Despite these concerns, the Russian government has funded the multi-billion U.S.$ Foundation for Advanced Research Projects in the Defense Industry, modeled after the U.S. Dept. of Defense's Defense Advanced Research Projects Agency (DARPA).

The Russian Ministry of Defence has been aggressively pushing the development of a new class of nuclear aircraft carriers as a means of securing Russian national interests anywhere in the world. These huge defense R&D programs are expensive and spread out over more than 10 years, but deemed essential for guaranteeing the country's scientific and technological capacity.

Russia's R&D Spending Growth



Source: Battelle/*R&D Magazine*

Russia's 2013 forecast $38.5 billion GERD accounts for about 2.6% of the expected global spending. Coincidentally, Russia also produces about 2.6% of the world output of 25,000 indexed research papers per year, according to Thomson Reuters. This overall average includes 7.4% of the total physics research papers, 6.9% of the space science papers, 6.8% of the geosciences papers, 4.9% of the chemistry papers, and 4.6% of the mathematics-based research papers.

2013 Global *R&D Funding Forecast*

BRIC — India

India has averaged greater than 7% annual GDP growth since 1997, but the current outlook is unusually uncertain. Real GDP growth for 2012 is expected to be close to 5%, according to the International Monetary Fund (IMF). The IMF's GDP growth forecast for 2013 increases to nearly 6% following various recent reforms. 2013 economic growth is expected to yield R&D spending growth of about 12.2% over that spent in 2012, which follows a relatively modest increase of 5% over what was spent in 2011.

A significant portion of India's R&D focuses on support for its services sector, which accounts for about two-thirds of India's GDP. India's pharmaceutical industry also accounts for a sizable portion of its R&D, especially in the generic drug market where Indian companies, such as Ranbaxy Laboratories, maintain a sizable global market share. These Indian generic manufacturers have also bought into European generic suppliers to increase their access to the European marketplace.

2013 GDP, billion US$, PPP	$5,020
2013 GERD, billion US$, PPP	$45.20
R&D/GDP	0.90%
Population, million	1,205
GERD/Person	$38
Published Research Papers	
1999-2003, Physics	11,700
2004-2008, Physics	17,300
1999-2003, Chemistry	21,200
2004-2008, Chemistry	33,500
Basic Research share	26%
Applied Research share	36%
Development Research share	32%
Other Research share	6%

Source: Battelle/*R&D Magazine*, UNESCO, Thompson Reuters

Low-cost R&D

India's dominance as the manufacturer of cheap medicines for poor people around the world is well established. While many of these drugs have been derived from western patented drugs, there also has been a strong supply of drug developers in Indian universities that were biased in favor of science to the detriment of engineering. As is typical for the global pharmaceutical business, a number of Indian pharmaceutical companies have purchased stakes in foreign pharmaceutical companies.

India's cultural tendency to supply inexpensive products for its large population carried over into the automotive marketplace, where Tata Motors has become a low-cost automotive supplier. With that success it has purchased foreign automotive manufacturers, such as Jaguar and Land Rover, to gain global market share and entry into foreign markets.

Indian government funding of R&D accounts for more than two-thirds of the total funding sources. Industry funding of R&D has steadily increased over the past 20 years, but still is less than a third of the total (compared to the U.S. and China, where industry accounts for more than two-thirds of all R&D funding). Government support of R&D in India tends to focus on classical objectives for public R&D funding, such as nuclear energy, defense, space, health and agriculture. The amount of R&D dedicated to basic research in India has also steadily increased from less than 20% of the total ten years ago to more than 26% now.

India's Industrial R&D

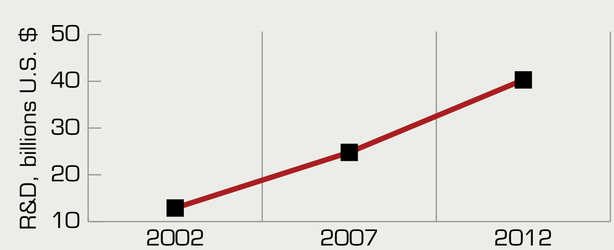
	2010 R&D mil. U.S. $	R&D, % Revenue
Tata Motors	397.8	1.50%
Prithvi Information	246.3	60.50%
Polaris Software	228.0	67.60%
Bharat Heavy	176.3	2.50%
Mahindra & Mahindra	157.2	2.50%
Lupin	112.7	9.30%
Infosys	112.0	1.90%
Reliance Industries	110.0	0.20%
Core Projects	96.2	53.40%
Bharat Electronics	67.2	5.90%

Source: Battelle/*R&D Magazine*, EU Industrial R&D Scoreboard

R&D Staffing Shortages

As noted on the chart on page 4 of this report, India has one of the smallest ratios of scientists and engineers per million people compared to other countries (137/million people). Part of this shortage is due to the lack of quality higher education institutions. Even with its large population, which is estimated to become the largest in the world by 2025, there is an estimated 25% shortage of engineers in the country. This is different than other countries in the region, such as China and South Korea, that produce larger numbers of engineers each year than any other countries in the world.

India's R&D Spending Growth



Source: Battelle/*R&D Magazine*

Continuing the trend it established more than a decade ago, China's commitment to R&D is expected to increase 11.6% in 2013, following an 11.3% increase in 2012. China's R&D is now 52% of that expected to be spent by the U.S. in 2013, compared to 43% just two years ago. China's R&D growth rate has slowed from the early 2000s when annual growth was in the 20% range, but this "slowdown" is more the result of a maturing role for R&D within the economy, rather than outright investment declines. China's economy surpassed that of Japan in 2010 and now is expected to surpass that of the U.S. in 2015, with its R&D investments not far behind. China's R&D could realistically match and quickly surpass that of the U.S. before the end of the decade.

China is investing in all aspects of R&D at record rates. It outproduces the U.S. in scientists and engineers (in part because it has a population that's more than four times larger). Its share of technical papers has steadily increased over the past 10 years, while the U.S. share has gone in the opposite direction every year. Peer-reviewed technical papers are a proxy for research activity. Indeed, the U.K.'s Royal Society estimates that China's total research paper output could surpass that of the U.S. in 2013. The report forecasts that this trend is likely to continue with China's technical paper share increasing to 22% by 2020, while the U.S. share falls to less than 10%.

2013 GDP, billion US$, PPP	$13,344
2013 GERD, billion US$, PPP	$220.20
R&D/GDP	1.65%
Population, million	1,343
GERD/Person	$164
Published Research Papers	
1999-2003, Physics	31,100
2004-2008, Physics	66,200
1999-2003, Chemistry	44,600
2004-2008, Chemistry	99,200
Basic Research Share	5%
Applied Research Share	13%
Development Research Share	82%

Source: Battelle/*R&D Magazine*, UNESCO, Thompson Reuters

The normalized citation impact of technical papers calculated by Thomson Reuters has similarly steadily increased over the past 10 years, while that for the U.S. has stagnated such that China's citation impact value of 1.5 now exceeds that of the U.S. (less than 1.4). Ten years ago, China's citation impact value was 1.2, while the U.S.'s was still 1.4. Much has been said about the modest quality of China's technology paper output, but in many areas, such as materials science, chemistry, and engineering, China is now a global leader.

Political Changes

China recently announced its once-every-ten-years change in political leadership—Xi Jinping replaced Hu Jintao. The change saw a downsized central committee that should result in faster decision making. No dramatic changes in science and technology policy have been announced or are expected—the changes made were more conservative than most China analysts expected and did not include high-profile reformers.

While much has been noted about an aggressive attack on government corruption, analysts observe that the long-term effects of the conservative political changes are likely to result in smaller productivity increases and slower changes in actual social and political reforms.

This is somewhat disquieting for China's R&D supporters, noting that party insiders were quoted as saying that sector monopolies and bureaucratic interests were somewhat responsible for the collapse of the Soviet Union. There also might be short-term economic policy changes as senior Chinese economic policy leaders reach mandatory retirement ages over the next few years starting in 2013.

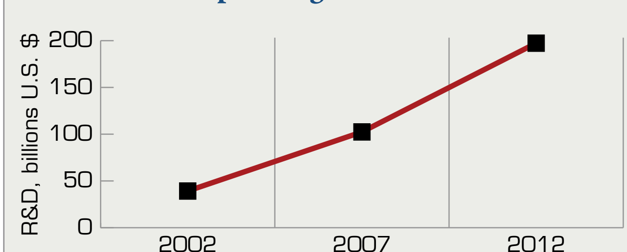
Numerous foreign and Chinese companies were anticipating the political changes to initiate changes in economic development, such as in construction and manufacturing to offset China's slowing economic growth. The political changes were announced in mid-November, so no new projects are expected in 2012, with any major new measures, such as those for railways and power grids, only starting to occur in 2013.

China's Industrial R&D

	2010 R&D mil. U.S. $	R&D, % Revenue
Huawei Technologies	2,302.7	8.60%
PetroChina	1,707.9	0.80%
China Railway Construction	1,354.9	2.10%
ZTE	1,143.7	11.30%
China Petroleum and Chemicals	697.5	0.30%
CSR China	352.5	3.80%
China Railway	301.2	0.50%
Metallurgical Corp.	258.8	0.90%
China Communications	227.2	0.60%
China Coal	216.4	2.10%

Source: Battelle/*R&D Magazine*, EU Industrial R&D Scoreboard

China's R&D Spending Growth



Source: Battelle/*R&D Magazine*

2013 Global *R&D Funding Forecast*

Europe

Half of the Top 40 R&D spending countries in the world (page 5) are in Europe, but they only account for 22.6% of the total global spending. Another 14 European countries increase that spending by $10.7 billion (23.4% of the global total). Over the past five years, Europe has continuously declined in its share of global R&D spending, while Asian countries have dramatically increased their share and the U.S. has declined slightly. Europe's debt crisis has weighed heavily on its overall R&D spending plans, as the European Union struggles with ways to prevent the collapse of the debt-ridden EU-member economies of Greece, Spain, Italy, and Portugal. The market uncertainties of these financing plans have affected the global economy from the U.S. to China.

Ten years ago, the EU set a goal of investing 3.0% of its combined GDP in R&D. Due to the debt crisis and the 2009-10 global recession, that goal was not met and the combined investment ratio now sits (mostly stable) at 1.88%, buoyed in most part to the large R&D spending plans of Germany and a few other countries (Sweden, Finland, and Denmark—all with long-standing R&D/GDP ratios greater than 3.0%).

2013 GDP, billion US$, PPP	$18,545
2013 GERD, billion US$, PPP	$349.50
R&D/GDP	1.88%
Population, million	711
GERD/Person	$491
Published Research Papers, Total	400,700
U.K. Research Papers	55,085
Germany Research Papers	104,600
France Research Papers	74,100
Italy Research Papers	49,700

Source: Battelle/*R&D Magazine*, UNESCO, Thompson Reuters

Economic Challenges

One of the linchpins in the European debt crisis (and survival of the Euro and possibly the EU itself) was establishment of the 2012 bailout plan for Greece. The bond-buying program established by the European Central Bank promises to ease the EU's financial problems and create an environment more conducive to R&D investments. Italy, Spain, Portugal, and Greece are all still expected to see diminished GDP in 2013 according to the International Monetary Fund, but substantially smaller declines than in 2012. Those four are the only European countries to see a decline compared to 11 countries that saw their GDP decline in 2012.

European academic research has shifted slightly over the past 10 years to be more like the U.S. academic system, which involves more diversity than its European counterparts. European universities followed the strict Humboldt model and focused primarily on research, which has been found to be not as efficient as a more balanced structure.

Europe's Industrial R&D

	2010 R&D mil. U.S. $	R&D, % Revenue	
Volkswagen	7,980.1	4.90%	Germany
Nokia	6,296.9	11.60%	Finland
Daimler	6,187.2	5.00%	Germany
Sanofi	5,598.1	13.60%	France
GlaxoSmithKline	5,584.0	13.20%	UK
Siemens	5,408.1	5.60%	Germany
Robert Bosch	4,876.3	8.10%	Germany
Bayer	4,094.6	9.20%	Germany
AstraZeneca	4,087.0	12.90%	UK
EADS	3,932.7	6.70%	Netherlands

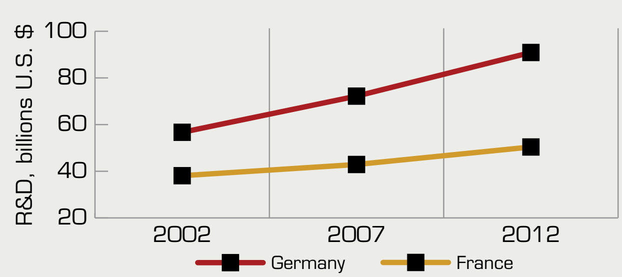
Source: Battelle/*R&D Magazine*, EU Industrial R&D Scoreboard

New Framework Programme

Over the past two decades, the EU's successful Framework Programme (FP) has worked to change the mostly national pattern of European universities to one of a much greater degree of cooperation between universities in different countries. Other inter-European academic programs such as the European Research Council and the European Institute of Innovation and Technology have been created to enhance the Framework Programme. The current 7th FP (2007-2013) will be replaced next year with the 8th FP (2014-2020). The 8th FP (named Horizon 2020) features a 46% budget increase over the 7th FP to $115 billion, with 8.5% of the EU's overall budget dedicated to research and innovation. It sets an objective for creating 3.0% of all EU's GDP invested in R&D by 2020.

The 8th FP also aligns priorities established for previous programs to common strategic priorities, focusing on societal challenges, competitiveness, and research excellence. The FP also eliminates gaps between stages of previous programs to coherent support across the innovation cycle and more standardized rules across all initiatives. Funding for the research and innovation projects has been greatly simplified for the 8th FP with common rules and funding schemes. Research project proposals were requested to be submitted before the end of 2011.

Europe's R&D Spending Growth



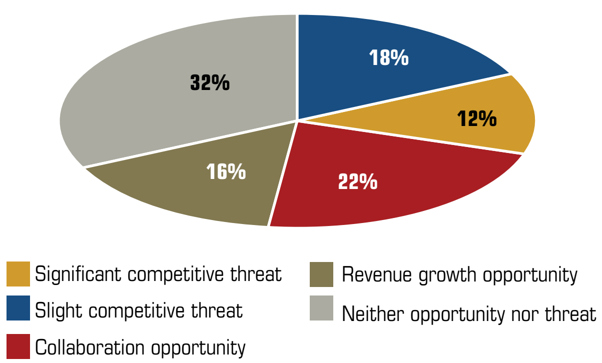
Source: Battelle/*R&D Magazine*

Rest of the World

The U.S., BRIC, and European countries account for about 70% of the R&D performed in the world. Countries in the rest-of-the-world (ROW) account for the remaining $500 billion. These countries are increasing their R&D investments at an average rate of nearly 5%. Major high-technology countries are included in this sector: Japan, Canada, South Korea, Taiwan, Singapore, Israel, Ukraine, and even Iran. There is no limit to the geographical distribution of R&D investments—each region and country has both drivers and limitations on R&D spending.

South Africa is considered the fifth member of the BRIC group, and South African representatives attend BRIC meetings. However, South Africa is not truly considered an emerging economy as much as Brazil, Russia, India, and China. Its GDP, R&D investment as a share of GDP, and R&D growth are all considered moderate compared to other major and emerging R&D spending countries.

Emerging Countries Opportunities and Threats



Source: Battelle/*R&D Magazine*

Major R&D Investors

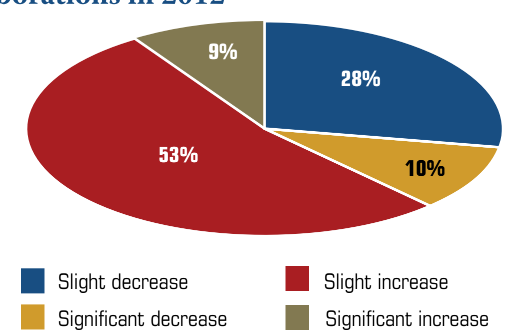
Japan, for example, has had a long-standing large R&D investment. R&D as a share of GDP is 3.5%, although it had reached 3.7% earlier in the decade. However, demographics, economics, and the Fukushima tsunami and nuclear disaster have had negative effects on Japan's R&D investments. Japan has an aging population, and academic enrollments have stagnated at the bachelor's level and rapidly declined at the graduate and doctorate levels. Part of this is also due to a decline in expected employment demand for these scientists and engineers. The 2009-10 global recession also affected the Japanese economy and the ability to strongly support R&D investments. Toyota's manufacturing quality problems affected its (and its suppliers) production and trade capabilities, which were further affected by the tsunami. The economic stresses have now largely abated and Japanese industrial output has resumed, along with increased R&D investments.

South Korea's R&D investment continues to increase at about 4% annually, with similar increases in its economy. South Korea ranks fifth in our Top 40 largest R&D investors with nearly 4% share of the global R&D investment, which is impressive considering it ranks 25th in population with 49 million and 15th in total GDP. South Korea invests about 3.5% of it GDP in R&D with the largest portion invested in industrial production and technology. About a third of the country's R&D spending is supplied by the government. Large corporate tax deductions are allowed by the government for R&D and facility investments. Patent registrations are also encouraged and have quadrupled over the past ten years. Scientific publications authored by South Korean researchers have similarly doubled over the past five years. And while the 2009-10 global recession affected the economies of numerous countries, the South Korean economy continued to grow through the recession.

Significant Others

Singapore is another strong R&D investor with nearly 1% of the total global output, especially when considering its population of only 5 million—less than a tenth of 1% of the world's population. Singapore GERD nearly tripled over the past ten years, and its R&D as a share of GDP increased from 1.9% to 2.7%, surpassing that of the U.S. GERD per capita also exceeds that of the U.S., the U.K., and Japan. Singapore ranks 19th out of 146 economies on the World Bank's Knowledge Economy Index (KEI). Singapore also leads the Southeast Asian regions in terms of the number of science and technology personnel. However, its relatively small size is a limitation on its long-term S&T growth potential. The number of scientific articles authored in Singapore is limited by its relatively small number of scientists and engineers, but it is still on a per capita level comparable to other countries in the region.

Changes in Foreign Outsourcing Collaborations in 2012



Source: Battelle/*R&D Magazine*

Israel is another ROW country with unique R&D capabilities and potential. Israel is the only country in the world with R&D as a share of GDP that exceeds 4% (4.2%). A significant portion of its $10.6 billion in 2013 R&D investments is allocated to development of new defense systems. Nine of the 13 east European countries fall within the ROW category, with an overall average R&D as a percent of GDP of 0.8% and an average R&D budget per country of $500 million. These countries' R&D budgets are expected to increase 2% in 2013, which is ahead of their expected GDP growth of 1.6%.

2013 Global *R&D Funding Forecast*

A View of the World of R&D

We present the results of our annual survey of the global researcher community. Improvements in the sampling strategy and distribution of the survey continue to increase and diversify the respondent base. This diversity provides a unique perspective on the global R&D community representing countries from Argentina to Vietnam. Not withstanding language and Internet-related issues, the respondent base reflects a good statistical sample of the leading R&D countries.

Global Respondent Profile

This year's response level reached 914, up from 713 last year, and represents the views from 70 countries. While the U.S. remained the single largest respondent country, the number of U.S. responses declined even as the overall response level increased by 28%. U.S. researchers accounted for only 26% of the responses in this year's survey, compared to 41% last year. The survey results saw significant increases in the number of respondents this year from both China and Russia. Other countries with 20 or more responses include Germany, the U.K, India, Spain, Japan, and Australia. Together, these nine countries account for 64% of the survey responses.

The increase in overall responses from China and Russia and a decline in corporate responses modified this year's research organization profile. Academic researchers account for 46% of this year's respondents. Research institutes account for the second largest share of respondents at 27%, up significantly from last year. Corporate researchers account for 21%, with government and other researchers accounting for 6%.

The response profile regarding the nature of the research performed by the respondents also was affected; with 37% of the respondents describing their research as basic in nature. Just under half (49%) of the researchers characterized their research activities as applied research. The decline in corporate responses likely led to the smaller share (6%) of respondents engaged in development activities, with science and engineering consulting or other technical services accounting for a slightly larger share at 7%. Finally, less than 1% of the respondents were engaged in related activities such as conservation or policy development organizations and natural history museums.

The diverse field of healthcare, medical, life science, and biotechnology R&D accounted for the largest share of respondents with 30%. Chemical, nanotech, and other advanced materials R&D accounted for the second largest share with 18%. Environmental and sustainability R&D and ICT R&D accounted for 11% and 9% of respondents, respectively. Of respondents' research areas, 12% fell outside of the 10 key areas we examine in detail with most of these researchers involved in astronomy/space sciences, geological sciences, or mathematics.

Critical R&D Performance Challenges for 2012 by Key R&D Performing Countries

China	Lack of Long-Term Budget/Perspective	Skilled Worker Shortages	Technology Solutions	Translating Research into Product
France	Limited External Funding	Lack of Long-Term Budget/Perspective	Limited Internal Budget	Internal Organizational Collaboration
Germany	Lack of Long-Term Budget/Perspective	Lack of Time to be Creative/Innovative	Prioritizing Research Efforts	Translating Research into Product
India	Interdisciplinary Research Efforts	Ability to Measure R&D Return on Investment (ROI)	Demands to Increase Speed of R&D Efforts	Finding New Collaborators
Japan	Lack of Long-Term Budget/Perspective	Competition	Lack of Time to be Creative/Innovative	Cost-Savings Requirements
Russia	Lack of Long-Term Budget/Perspective	Limited External Funding	Limited Internal Budget	Collaboration with External Organizations
South Korea	Development Time	Competition	Lack of Time to be Creative/Innovative	Acceptable R&D Return on Investment (ROI)
U.K.	Lack of Time to be Creative/Innovative	Lack of Long-Term Budget/Perspective	Limited External Funding	Limited Internal Budget
U.S.	Limited External Funding	Limited Internal Budget	Lack of Time to be Creative/Innovative	Lack of Long-Term Budget/Perspective
All Respondents	Limited External Funding	Limited Internal Budget	Lack of Long-Term Budget/Perspective	Lack of Time to be Creative/Innovative

Source: Battelle

Collaborative R&D

We explored the collaborative nature of R&D in this year's survey. Nearly all (94%) of respondents are involved in collaborations of some type. Regardless of their organizational type, 78% of all respondents collaborated with academic/university researchers in the past year. Collaborating with research institutes is the second most likely collaboration mode, cited by 56% of the respondents.

Examining country-level collaboration reveals some additional insights. Researchers from Germany, the U.K., and Sweden, regardless of the organization type they work for, are more likely to collaborate with corporate researchers, with 60% or more of their researchers involved in such joint research. Though affected by research areas and economic structures, India and Russia are at the opposite end of the spectrum with only 18% and 24% of researchers, respectively, reporting corporate collaborations in the past year. China's level of corporate collaboration is better at 39%, but still below the all-researcher average of 46%. It is interesting to note, however, that only 16% of researchers from Russia and China report collaboration with government R&D organizations, indicating that government collaborations are not being significantly substituted for corporate partnerships in these countries.

Critical R&D Challenges & Issues

When asked about the most critical challenges to performing their R&D activities, the respondents as a whole identified four challenges as most important: limited external funding, limited internal budget, lack of long-term budget and perspective, and the lack of time to be creative and innovative. These challenges were each identified by 35% or more of the respondents. These challenges are still key when focusing solely on basic and applied researchers. However, when examining the responses from researchers focused on development work, after limited internal budget the next two most cited challenges are prioritizing research efforts and translating research into products.

As expected, there is a certain commonality among the critical R&D challenges when examined by country. However, most countries register some specific challenges that are distinct. For example, among top R&D performing countries, limited external funding is only cited as a key challenge by researchers in France, Russia, the U.K., and the U.S. Chinese researchers cite skilled worker shortages as one of their top challenges, while Russian and French researchers are faced with collaboration challenges.

India and South Korea, however, present unique sets of challenges. Indian researchers are challenged with both interdisciplinary efforts and finding new collaborators. They also recognize a need to measure R&D return on investment. South Korean researchers cite the lack of development time, in addition to the more common lack of time to be creative. They also cite competition and demonstrating acceptable return on investment as key challenges.

As part of this annual survey we seek to uncover global issues of importance that are influencing the direction of future R&D efforts. Overall, the single largest issue of importance among all respondents is improving governments' understanding of science and technology issues, with 51% of respondents citing this issue. However, over the three years of this survey we have seen a steady increase in the importance of a variety of "green" issues cited by our respondents. More than 40% of the respondents cite

Key Global Issues Influencing Future R&D Efforts by R&D Performing Countries

China	Climate Change/Global Warming	Environmental Clean-up & Remediation	Demand for Renewable & Sustainable Energy
France	Citizens' Understanding of Science & Technology Issues	Healthcare for the Aging	Demand for Renewable & Sustainable Energy
Germany	Demand for Renewable & Sustainable Energy	Sustainable Development	Climate Change/Global Warming
India	Sustainable Development	Governments' Understanding of Science & Technology Issues	Environmental Clean-up & Remediation
Japan	Carbon Constraints and CO_2 Capture/Management	Environmental Clean-up & Remediation	Climate Change/Global Warming
Russia	Governments' Understanding of Science & Technology Issues	Citizens' Understanding of Science & Technology Issues	Healthcare for the Aging
South Korea	Climate Change/Global Warming	Governments' Understanding of Science & Technology Issues	Healthcare for the Aging
U.K.	Climate Change/Global Warming	Governments' Understanding of Science & Technology Issues	Demand for Renewable & Sustainable Energy
U.S.	Governments' Understanding of Science & Technology Issues	Citizens' Understanding of Science & Technology Issues	Demand for Renewable & Sustainable Energy
All Respondents	Governments' Understanding of Science & Technology Issues	Demand for Renewable & Sustainable Energy	Sustainable Development

Source: Battelle

2013 Global *R&D Funding Forecast*

Global Researcher Views of Leading Countries in R&D by Research/Technology Area

Agriculture & Food Production	Automotive & Other Motor Vehicle	Commercial Aerospace, Rail & Other Non-Auto. Transport	Military Aerospace, Defense & Security	Chemicals, Nanotech & Advanced Materials	Energy Generation & Efficiency	Environmental & Sustainability	Healthcare, Medical, Life Science & Biotech	Information & Comm. (ICT)	Instruments & Other Non-ICT Electronics
U.S.	Germany	U.S.	U.S.	U.S.	U.S.	Germany	U.S.	U.S.	U.S.
China	Japan	France	China	Japan	Germany	U.S.	U.K.	Japan	Germany
Germany	U.S.	Germany	Russia	Germany	Japan	Japan	Germany	China	Japan
Australia	South Korea	China	U.K.	China	China	U.K.	Japan	Germany	China
Brazil	China	Japan	France	U.K.	U.K.	Sweden	Switzerland	South Korea	South Korea

Source: Battelle

the demand for renewable energy, the need for sustainable development, and climate change/global warming as important issues shaping the direction of their future research. Additionally, more than 40% of respondents see citizens' understanding of science and technology issues as impacting their future research.

Though these issues are generally reflected globally, certain issues do impact the research directions of various countries differently. Not surprisingly, environmental clean-up and remediation is a key issue for both Japan and China. Healthcare for the aging is a key issue for three countries—France, Russia, and South Korea.

Views of R&D Leaders

To complete our survey of global researcher views, we asked respondents to provide their view on what countries' researchers (including academic, industrial, and government researchers) were performing the leading R&D efforts across 10 research/technology areas. Even with a significant increase in respondents from China and Russia, the global research community's view of the top five countries leading global R&D in these areas remained surprisingly consistent compared to last year.

The U.S. is seen as a top five research country across all 10 areas, leading in eight. China is among the leaders in eight of the 10 areas, but dropped out of the top five in environmental and healthcare. Germany continues to remains a top five research country in every area but defense, including moving into the top spot in automotive. South Korea moved up one position in automotive and broke into the top five in both ICT and instruments. Other notable changes over last year include Australia and Switzerland reaching a top five position in agriculture and healthcare, respectively, and India dropping out of the top five in ICT.

As part of this year's survey we also asked our global researcher respondents to identify what companies they felt were doing the most innovative R&D. We show the results of our survey in conjunction with similar research performed by both Booz & Co. and KPMG in 2012, though each had a different respondent base and perspective. Even with the methodological differences, there exists a strong recognition of the most innovative global compa-

Views of Global Researchers

As part of our Global Researcher Survey we ask our respondents to comment on the status and future of R&D. Below are a few thought provoking views from around the world.

The nexus of water, food and energy will drive security of planet earth. Any innovative technology that makes a positive impact in these areas will be beneficial.

– Academia /Singapore

The big challenge for the global research community is to tackle problems in primary healthcare and primary education and invest more in development of disruptive technologies that can positively impact social sector development.

– Corporation/India

I believe that the ever changing consumer demand, especially in emerging countries, will continue to drive innovation and research efforts. The companies who are able to handle consumer understanding, project complexity and production efficiency most effectively will gain market share globally.

– Multinational Corporation/Germany

There is an ongoing shift towards, and a great need for, integrative and applied scientific research (rather than siloed and theoretical research).

– Academia/Japan

Eventually I expect that the US, Western Europe and Japan will see their predominance in research, innovation, scientific, etc. erode, as education and sophistication of the rest of the world advances. At some point it should become feasible to have a world-class intellectual enterprise centered in China, India, Russia, etc., sustained by world-class educational institutions, IP protection, and reduced cost of living.

– Multinational Corporation /U.S.

Perspectives on Corporate Innovation – Respondent Rankings

Company	Global Researcher Survey Respondents	Booz & Co. Top 10 Most Innovative Companies	KPMG Top Innovative Companies
Apple	1	1	1
Google	2	2	2
Samsung	3	4	4
Microsoft	4	6	3
Intel	5	NR	NR
IBM	6	9	5
General Electric	7	5	NR
Siemens	8	NR	NR
Toyota	9	7	NR
Amazon	10	10	7
Facebook	12	NR	6
Procter & Gamble	22	8	NR
3M	26	3	NR
Oracle/Sun Microsystems	NR	NR	8

Source: Battelle Survey, Booz & Co., KPMG

nies. Across all three surveys, Apple and Google were ranked 1st and 2nd. Samsung, which was ranked 3rd in the global researcher survey, was ranked 4th in the two comparison efforts. Microsoft was ranked fourth in the global researcher survey, but third in the KPMG effort and sixth in the Booz & Co. analysis. At this point, the results of our global researcher survey begin to show some significant comparative differences, most likely due to the universe of potential respondents (both Booz & Co. and KPMG focus solely on leading corporate respondents, and KPMG is further focused primarily on information technology-related companies). Our respondents ranked Intel fifth and Siemens eighth in terms of companies doing the most innovative research, while both are not ranked among the leaders in the two comparison analyses. One interesting finding within this comparative analysis is that both Procter & Gamble and 3M were ranked in the Booz & Co. Top 10, but ranked 22nd and 26th respectively in our survey. The most likely source of this difference is our broader global research community respondent base is less familiar with the R&D efforts of these two more consumer-oriented U.S. companies. Finally, even though 30% of our global researcher respondents considered themselves to be in the broadly defined healthcare/life science segment, no life science company was ranked in the top 10 by our respondents, however, Roche/Genentech was ranked 11th.

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Resources

The following Web sites are good sources of information related to the global R&D enterprise. Much of the information in this report was derived from these sources, which are certainly not all-inclusive.

American Association for the Advancement of Science
www.aaas.org

Battelle Memorial Institute
www.battelle.org

Booz & Co.
Global Innovation 1000
www.booz.com

China Ministry of Science and Technology
www.most.gov.cn

Chinese Academy of Sciences
english.cas.cn

European Commission Research
ec.europa.eu/research/index_en.cfm

European Industrial Research Management Association (EIRMA)
www.eirma.org

European Union Community R&D Information Service (CORDIS)
cordis.europa.eu/en/home.html

International Monetary Fund
www.imf.org

Information Technology & Innovation Foundation (ITIF)
www.itif.org

KPMG
Technology Innovation Survey
www.kpmg.com

MIG, Inc.
IMPLAN Models
www.implan.com

Organization for Economic Cooperation & Development (OECD)
www.oecd.org

R&D Magazine,
Advantage Business Media
www.rdmag.com

Schonfeld & Associates
www.saibooks.com

Thomson Reuters
www.thomsonreuters.com

The World Bank
www.worldbank.org

U.S. National Science Foundation
www.nsf.gov

U.S. Securities & Exchange Commission (EDGAR database)
www.sec.gov/edgar.shtml

White House Office of Science & Technology Policy
www.ostp.gov