IDC HPC ROI Research Update:

Economic Models For Financial ROI And Innovation From HPC Investments

Earl Joseph, ejoseph@idc.com
Steve Conway, sconway@idc.com
Robert Sorensen, bsorensen@idc.com
Kevin Monroe, kmonroe@idc.com

December, 2016

Grant References

- **The authors thank DOE for its insights and guidance on and funding of this grant-based research project**
  - This study is based upon work funded by the U.S. Department of Energy Office of Science, Office of Advanced Scientific Computing Research, and the National Nuclear Security Administration, under award number DE-SC0012576.

- **DOE Program Managers:**
  - Christine Chalk, 301-903-5152, christine.chalk@science.doe.gov, and Barbara J. Helland, 301-903-3127, barbara.helland@science.doe.gov, U.S. Department of Energy Office of Science, Germantown Building, 1000 Independence Avenue, S.W. Washington, D.C., 20585-1290, and Doug Wade in National Nuclear security Administration (NNSA).

- **Administrator/Contracting Officer:**
  - Warren Riley, 630-252-2485, warren.riley@ch.doe.gov, U.S. Department of Energy Office of Acquisition and Assistance, 9800 South Cass Avenue, Argonne, Illinois, 60439

- **IDC Reporting:**
  - Principal investigator: Earl C. Joseph, Ph.D., 612-812-5798, ejoseph@idc.com
  - Senior technical project manager: John Daly, 508-935-4643, jdaly@idc.com

IDC
Analyze the Future

Project Overview: Why It's Key To DOE

- World scientific leadership and innovation leadership are becoming more dependent on the use of HPC/supercomputers every year
- Economic leadership increasingly results from a nation's or an industry's or an enterprise's application of supercomputers in innovative and productive ways
- Many countries are putting in place plans to gain leadership in innovation and economic progress by more broadly applying HPC/supercomputing across many different industries and segments (like China, Russia, Europe, Japan and other Asian countries)
- And it supports the new White House NSCI initiative

Research Background

- **2013 pilot study:**
  - Tested 3 approaches and set the models
  - Populated the models with 208 cases of scientific innovation and industrial ROI (it is now at 673 examples)
  - Created a new innovation index

- **Three-year study: sponsored by DOE Science/NNSA**
  - Refine the models as needed
  - Collect many more RPOI examples/data points:
    - Dense collection in the U.S., plus around the world
    - Focus on Japan, China and Germany
    - Drive to get more job creation data
  - Drive towards publication

IDC
Analyze the Future

Background: Project Overview

A study that describes how HPC investments are related to improved economic success and increased scientific innovation

The study includes large scale data collection to populate two unique models:

1. A macroeconomic model which depicts how HPC investments result in economic advancements in the form of ROI, GDP growth and jobs
2. **Now Three** Innovation Indexes that measure and compares innovation levels, based on the level of applying HPC computing resources towards scientific and technical advancement

IDC
Analyze the Future

The Financial ROI Models Used

The Financial ROI models:

1. ROI based on revenues/GDP generated, divided by HPC investment
2. ROI based on cost-savings and/or profits generated, divided by HPC investment
3. ROI based on jobs created (and the HPC investment required per job created)

The ROI models show variances by:

- Industry & sector
- Country
- Organization size

IDC
Analyze the Future

Changes Made in 2016

Data collection is more difficult than we had expected:

- Over 50% of the examples are rejected for various reasons
- Many researchers have agreed to participate, but a much smaller number actually participate
- Still requires multiple face-to-face visits to collect results

Solutions added:

- Added a person in China to directly collect ROI examples (Mengland Shi), each requires multiple face-to-face meetings
  - Results so far: 126 ROI/ROR examples
- Added a part time person in Japan (Nishi Katsuya), each survey requires multiple face-to-face meetings
  - Results so far: 79 ROI/ROR examples
- Added a program to motivate HPC center directors to help push their researchers to participate
  - Results so far: Germany has started, Riken & Blue Waters were the test-beds

Changes Made in 2016

- The term "innovation ROI" isn't well understood by many people, in a number of countries
  - So we now refer to it as ROR = Return on Research

The Updated Innovation Models Used

Three innovations indexes are now being used:

1. **Based on the importance of the innovation**
2. **How broadly the innovations impact different organizations**
3. **A combined score to create innovation "Class" levels**

The innovations are also sorted by the primary area:

1. Better Products
2. Major Scientific Breakthrough
3. Cost Saving
4. Created New Approach
5. Discovered Something New
6. Helped Society
7. Helped Research Program

Changes Made in 2016: New Innovation "Class" Scale

- Expanded the innovation indexes by adding a new innovation "Class" scale:

  Class 1 innovations – One of the top 2-3 innovations in a field over the last ten years PLUS useful to over 10 organizations

  Class 2 innovations -- One of the top 5 innovations in a field over the last ten years PLUS useful to over 10 organizations

  Class 3 innovations – One of the top 5 innovations in a field over the last ten years PLUS useful to at least 5 organizations

  Class 4 innovations – One of the top 10 innovations in a field over the last ten years PLUS useful to at least 5 organizations

  Class 5 innovations – One of the top 25 innovations in a field over the last ten years PLUS useful to at over 10 organizations

  Class 6 innovations – One of the top 25 innovations in a field over the last ten years PLUS useful to at least 2 organizations

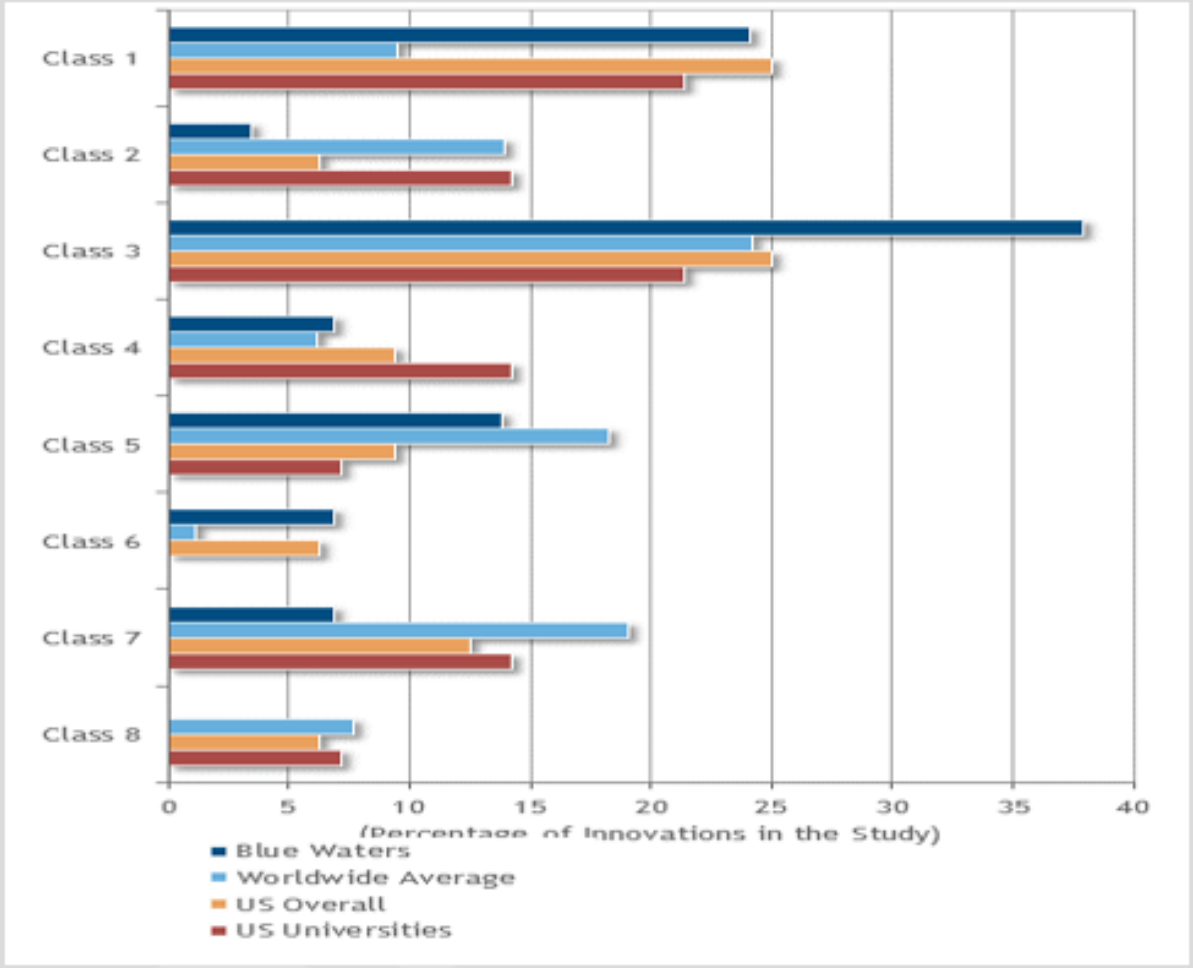
  Class 7 innovations – One of the top 50 innovations in a field over the last ten years PLUS useful to at least 2 organizations

  Class 8 innovations – The rest of the innovations in the study

Changes Made in 2016: New Innovation "Class" Scale – Blue Waters Example

FIGURE 8

Blue Water Innovations: Innovation Class Level



Source: IDC 2016

IDC Analyze the Future

The Innovation Models Used: Additional Data Collected

Plus the innovations are sorted by:

1. Basic Research / Major Innovations
2. Applied Research / Incremental Innovations

The Innovation models can be sorted for variances by:

- Industry sector
- Country
- Organization size
- Government, Industry and Academia

December 2016
Research Update

IDC
Analyze the Future

Current Database Demographics

- Total ROI & ROR examples (673):
  - Financial ROI examples = 148
  - Innovation ROR examples = 525

Accomplishment Type	Count of Accomplishment Type
Financial ROI	148
Innovation	525
Grand Total	**673**

Note: This is up from July 30th, 2015 when we were at 329

Note: We are finally at a stage in the research that we feel comfortable starting the publication process!

IDC Analyze the Future

Current Database Demographics

- By country:

Country	Count of Accomplishment Type
China	126
France	17
India	1
UK	120
US	304
Italy	9
Germany	10
Canada	1
Slovenia	2
Netherlands	1
Australia	2
Japan	79
South Africa	1
Grand Total	**673**

IDC Analyze the Future

Current Database Demographics

- By sector:

Sector	Count of Accomplishment Type
Academic	362
Government	76
Industry	235
Grand Total	**673**

IDC Analyze the Future

Current Database Demographics

- By industries:

Q3: Industry	Count of Accomplishment Type
Academic	363
Agriculture	1
Defense	3
Entertainment	6
Environmental Safety	1
Financial	41
Government	76
Insurance	1
Life Sciences	31
Manufacturing	114
O&G	21
Retail	3
Telecomm	4
Transportation	8
Grand Total	**673**

IDC Analyze the Future

December 2016
Study Results:
The Financial ROI From HPC

IDC
Analyze the Future

New Findings:
Primary Financial ROI Results

Results continue to indicate very substantial returns for investments in HPC:

- **$515 dollars on average in revenue** per dollar of HPC invested.
- **$52 dollars on average of profits** (or cost savings) per dollar of HPC invested.

Organization Type	Average of Revenue $ per HPC $	Average of Profit or Cost Saving $ per HPC $
Academic	1,150.2	41.3
Company	441.8	41.3
Government	1,205.7	141.5
Grand Total	**515**	**52**

IDC Analyze the Future

New Findings: Financial ROI Model – By Industry

Results continue to indicate very substantial returns for investments in HPC:

- **2,335 jobs were created across these financial ROI projects**

Q3: Industry	Average of Revenue $ per HPC $	Average of Profit or Cost Saving $ per HPC $	Sum of Total Jobs Added	Count of Accomplishment Type
Academic	1150.2	44.3	14	21
Defense	75.0	5.3	0	2
Financial	725.7	80.5	602	31
Government	1205.7	140.8	42	15
Insurance	71.4		5	1
Life Sciences	160.0	40.9	48	13
Manufacturing	83.0	20.2	678	43
O&G	418.6	46.0	100	10
Retail	30.3	12.3	49	3
Telecomm	10.0	10.0	420	2
Transportation	1804.3	15.6	377	7
Grand Total	**515**	**52**	**2,335**	**148**

IDC Analyze the Future

New Findings: Financial ROI Model – By Country

Country	Average of Revenue $ per HPC $	Average of Profit or Cost Saving $ per HPC $	Sum of Total Jobs Added	Count of Accomplishment Type
China	9	3	196	21
France	593	81	30	6
UK	635	48	1376	47
US	373	39	680	50
Italy	10	8	0	3
Germany	15	16	25	7
Slovenia		65	0	1
Japan	2709	278	28	13
Grand Total	**515**	**52**	**2,335**	**148**

Note: The data set today isn't complete enough to make full country-to-country comparisons. There are also differences by country on how sites calculate returns and costs, this causes variations in the data.

IDC Analyze the Future

New Findings: Job Creation

The overall average HPC investment cost per job created was $270K

- 225 sites reported job creation
  - A total of 5,748 jobs were created from these examples (at the 225 sites):
    - 2,335 jobs were created from the financial ROI examples
    - 3,413 jobs were created from the innovation ROR examples
  - On average 25.6 jobs were created from the HPC projects at these sites

New Findings: Job Creation

Job creation by sector:

Sector	Sum of Total Jobs Added	Average of HPC $K per New Employee
Academic	1,632	$107 K
Government	196	$473 K
Industry	3,920	$266 K
Grand Total	**5,748**	**$270 K**

IDC Analyze the Future

New Findings: Job Creation

Job creation by industry:

Q3: Industry	Sum of Total Jobs Added	Average of HPC $K per New Employee
Academic	1,632	$107 K
Financial	857	$255 K
Government	196	$473 K
Insurance	5	$175 K
Life Sciences	134	$88 K
Manufacturing	1,920	$365 K
O&G	158	$291 K
Retail	49	$152 K
Telecomm	420	$179 K
Transportation	377	$238 K
Grand Total	**5,748**	**$270 K**

IDC Analyze the Future

New Findings: Job Creation

Job creation by country:

Country	Sum of Total Jobs Added	Average of HPC $K per New Employee	Count of Accomplishment Type
China	326	$206 K	126
France	90	$59 K	17
India	-		1
UK	1,781	$344 K	120
US	3,294	$97 K	304
Italy	-		9
Germany	26	$80 K	10
Canada	-		1
Slovenia	40	$3 K	2
Netherlands	16	$750 K	1
Australia	-		2
Japan	165	$608 K	79
South Africa	10		1
Grand Total	**5,748**	**$270 K**	**673**

IDC Analyze the Future

December 2016 Study Results: Innovation ROR (Return On Research)

IDC Analyze the Future

New Findings: The Mix Of Innovation Types (For The Innovation Projects)

The average cost of an innovation in the INNOVATION ROR projects was $12.7 million:

Q4: Primary Innovation / ROI	Count of Accomplishment Type2	Average of HPC $M per Innovation	Count of Q8: Basic	Count of Q8: Applied
Better Products	95	$3.5 M	22	72
Cost Savings	16	$1.6 M	8	9
Created New Approach	233	$1.2 M	185	50
Discovered Something New	40	$3.0 M	27	13
Helped Society	42	$6.4 M	21	21
Scientific Breakthrough	55	$80.3 M	49	8
Support Research Programs	44	$36.7 M	19	26
Grand Total	**525**	**$12.7 M**	**331**	**199**

IDC Analyze the Future

New Findings:
Innovations – Basic vs. Applied

Sector	Count of Q8: Basic	Count of Q8: Applied	Count of Q8: Basic/ Applied
Academic	265	80	341
Government	37	27	61
Industry	29	92	123
Grand Total	**331**	**199**	**525**

IDC
Analyze the Future

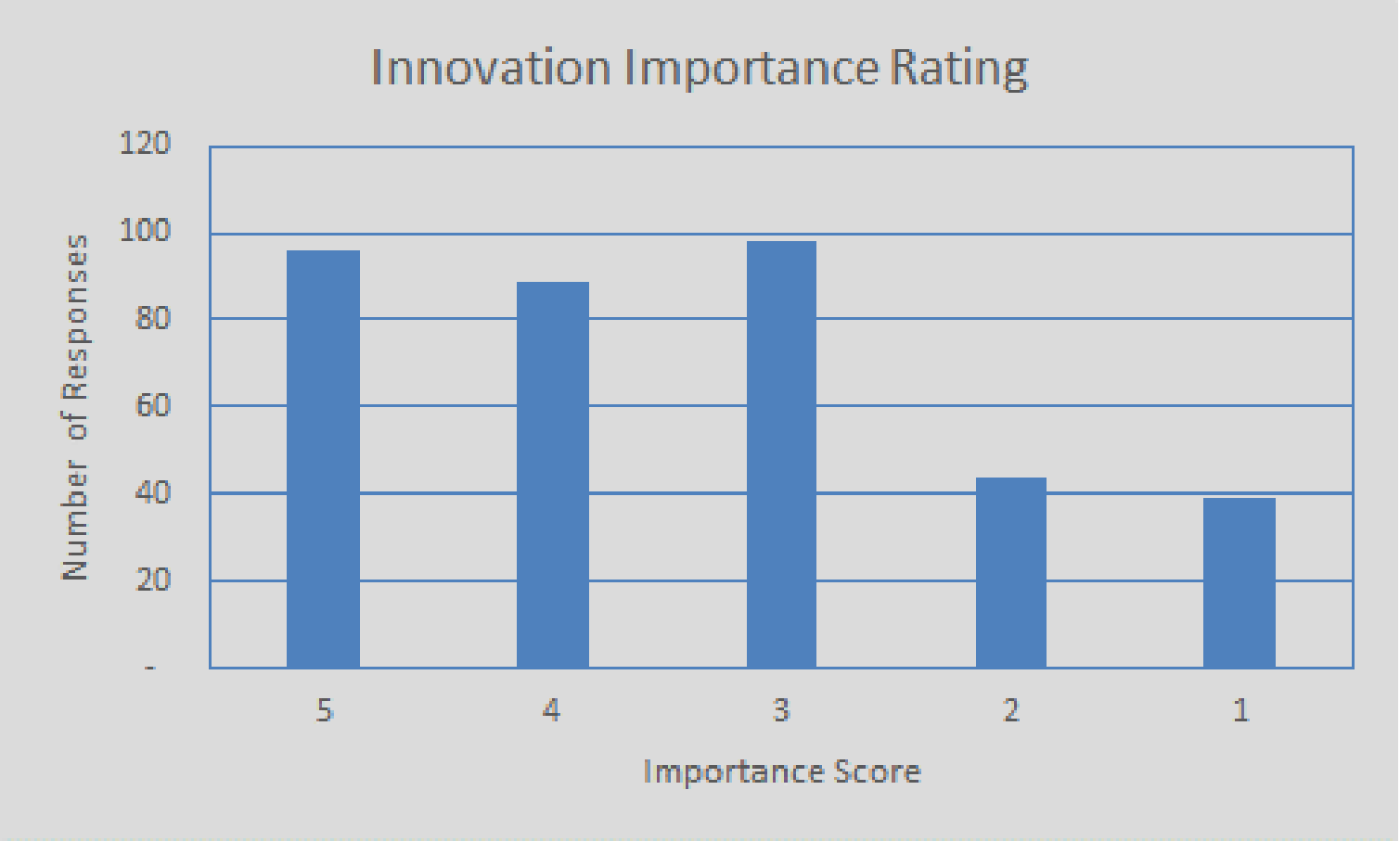
New Findings: Innovations – By Country

Country	Count of Q8: Basic	Count of Q8: Applied	Count of Q8: Basic/ Applied
China	72	33	105
France	1	10	11
India	1		1
UK	53	20	73
US	161	96	254
Italy		6	6
Germany	1	2	3
Canada	1		1
Slovenia		1	1
Netherlands		1	1
Australia	1	1	2
Japan	40	28	66
South Africa		1	1
Grand Total	**331**	**199**	**525**

Note: The data set today isn't complete enough to make country-to-country comparisons.

IDC Analyze the Future

New Findings: The Innovation IMPORTANCE Index



5. One of the top 2 to 3 innovations in the last decade
4. One of the top 5 innovations in the last decade
3. One of the top 10 innovations in the last decade
2. One of the top 25 innovations in the last decade
1. One of the top 50 innovations in the last decade

IDC Analyze the Future

New Findings: The Innovation IMPORTANCE Index

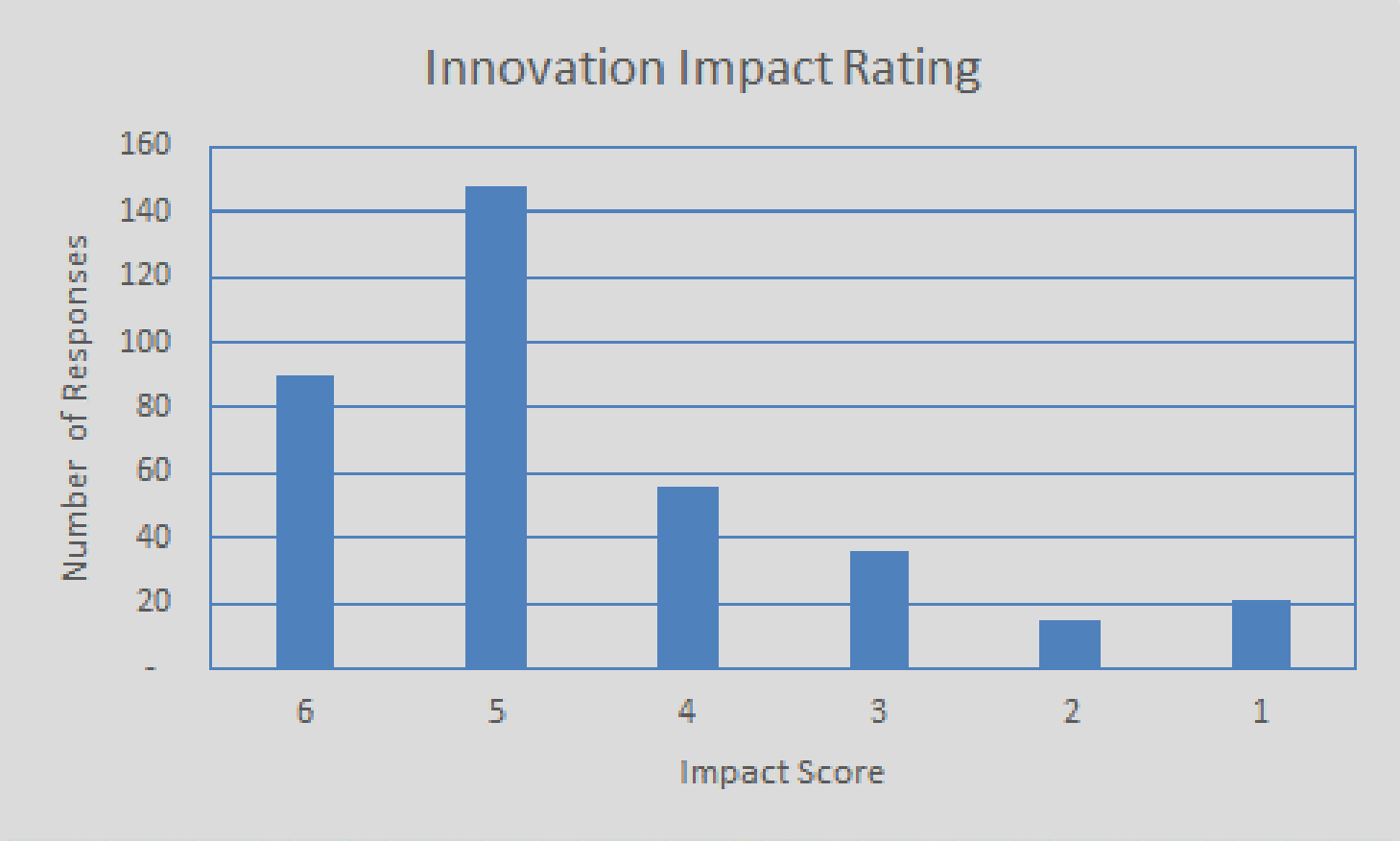
Average IMPORTANCE innovation rating = 3.43

Q9: New Innovation Index #1 Importance	Count of Accomplishment	Average of HPC $M per Innovation	Sum of Total Jobs Added
5	96	39.0	1,487
4	89	31.5	256
3	98	1.1	439
2	44	23.0	1,029
1	39	0.9	58
Grand Total	**366**	**19.1**	**3,268**

5. One of the top 2 to 3 innovations in the last decade
4. One of the top 5 innovations in the last decade
3. One of the top 10 innovations in the last decade
2. One of the top 25 innovations in the last decade
1. One of the top 50 innovations in the last decade

IDC Analyze the Future

New Findings: The Innovation IMPACT Index



6. It is useful to over 50 organizations
5. An innovation that is useful to 10 to 49 organizations
4. An innovation that is useful to 6 to 10 organizations
3. An innovation useful to 2 to 5 organizations
2. An innovation only useful to 1 organization
1. An innovation that is recognized ONLY by experts in the field

IDC Analyze the Future

New Findings: The Innovation IMPACT Index

Average IMPACT innovation rating = 4.54

Q10: New Innovation Index #2 No. Org's Impacted	Count of Accomplishment Type	Average of HPC $M per Innovation	Sum of Total Jobs Added
6	90	9.8	1,260
5	148	18.2	893
4	56	17.9	38
3	36	1.3	49
2	15	0.8	9
1	21	81.3	1,020
Grand Total	**366**	**19.1**	**3,268**

6. It is useful to over 50 organizations
5. An innovation that is useful to 10 to 49 organizations
4. An innovation that is useful to 6 to 10 organizations
3. An innovation useful to 2 to 5 organizations
2. An innovation only useful to 1 organization
1. An innovation that is recognized ONLY by experts in the field

IDC Analyze the Future

Changes Made in 2016: New Innovation "Class" Scale

- Expanded the innovation indexes by adding a new innovation "Class" scale:

  Class 1 innovations – One of the top 2-3 innovations in a field over the last ten years PLUS useful to over 10 organizations

  Class 2 innovations -- One of the top 5 innovations in a field over the last ten years PLUS useful to over 10 organizations

  Class 3 innovations – One of the top 5 innovations in a field over the last ten years PLUS useful to at least 5 organizations

  Class 4 innovations – One of the top 10 innovations in a field over the last ten years PLUS useful to at least 5 organizations

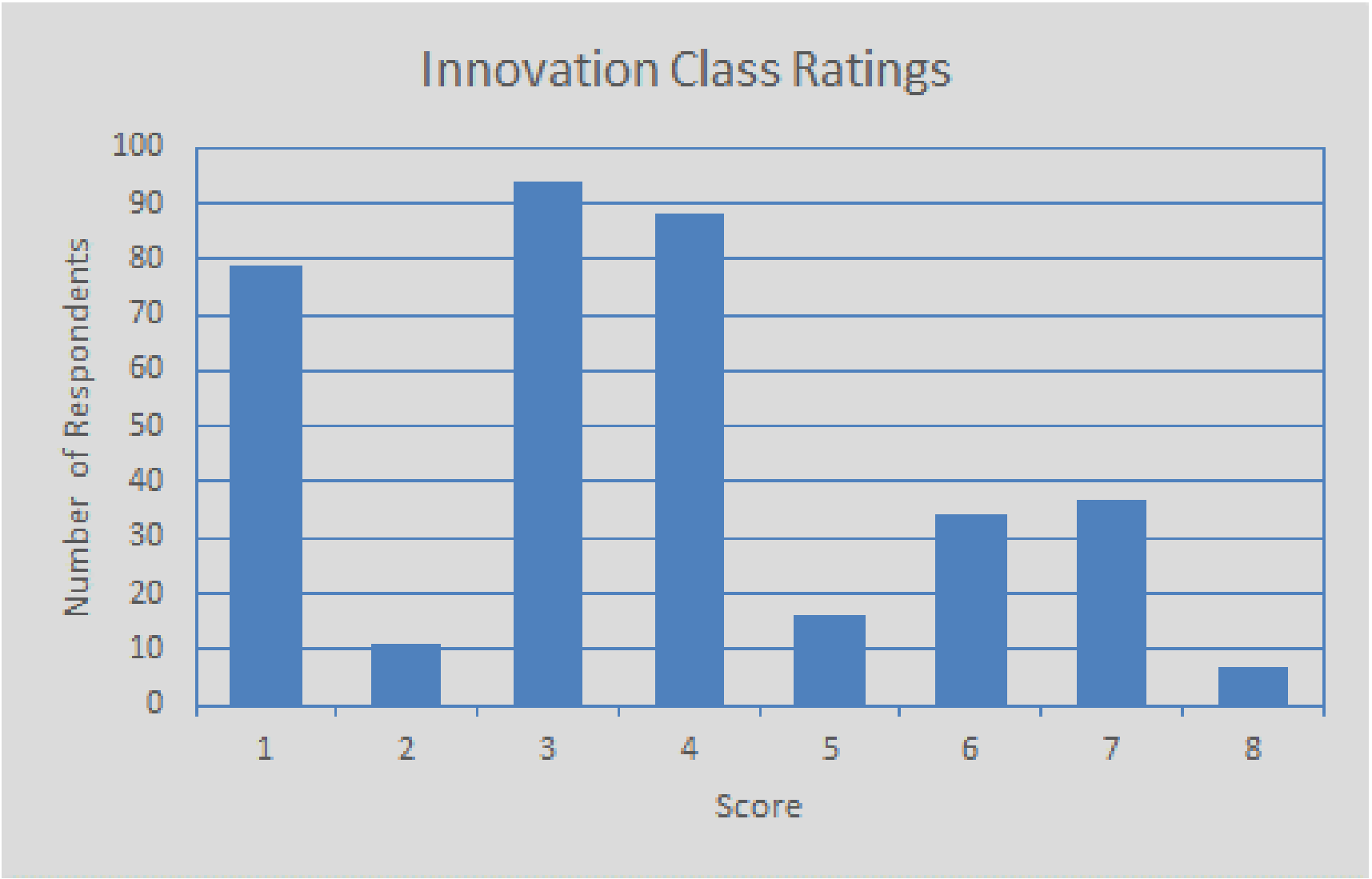
  Class 5 innovations – One of the top 25 innovations in a field over the last ten years PLUS useful to at over 10 organizations

  Class 6 innovations – One of the top 25 innovations in a field over the last ten years PLUS useful to at least 2 organizations

  Class 7 innovations – One of the top 50 innovations in a field over the last ten years PLUS useful to at least 2 organizations

  Class 8 innovations – The rest of the innovations in the study

New Findings: The New INNOVATION CLASS Index



New Findings: The INNOVATION CLASS Index

Average innovation Class rating = 3.64

Innovation Class	Count of Accomplishment Type	Average of HPC $M per Innovation	Sum of Total Jobs Added
1	79	33.2	1,449
2	11	125.9	28
3	94	30.6	266
4	88	1.1	434
5	16	1.7	14
6	34	4.0	15
7	37	21.7	1,063
8	7	0.8	-
Grand Total	**366**	**19.1**	**3,268**

IDC Analyze the Future

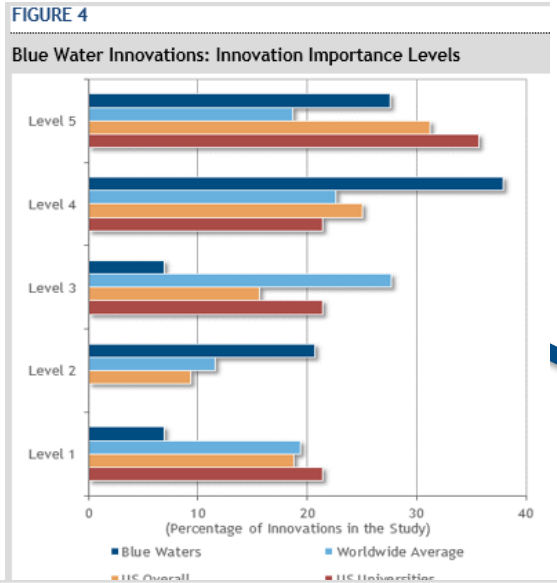
New Findings: Success Stories

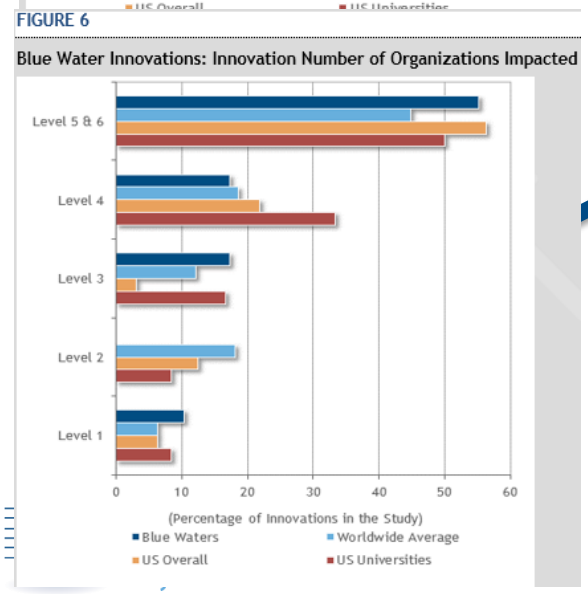
Note that an additional outcome of this research is an expansive list of HPC success stories

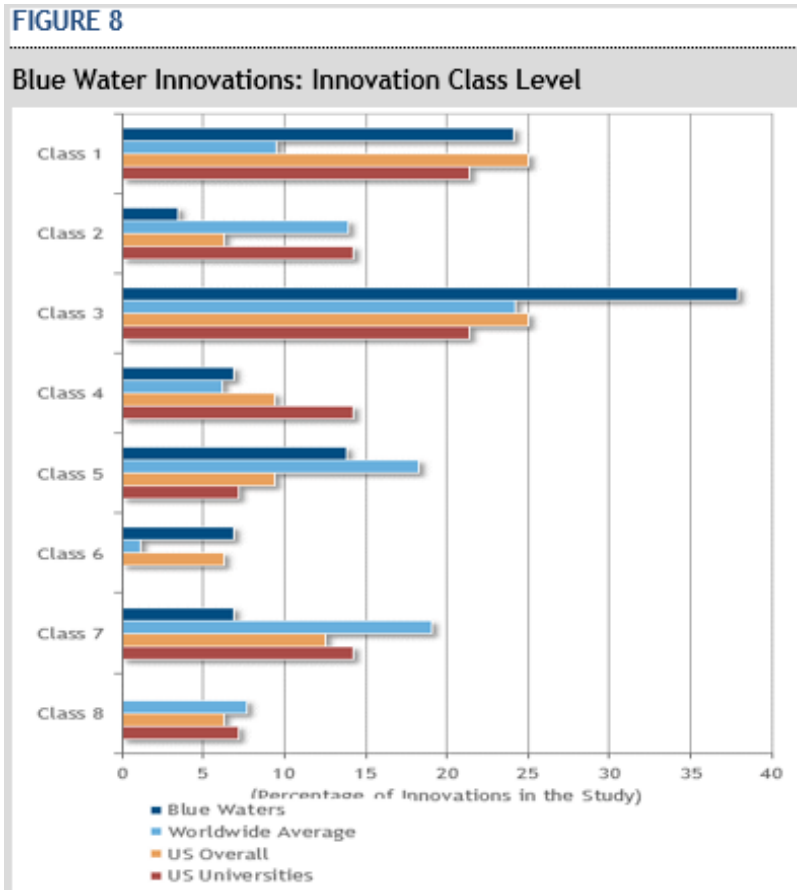
- These can be used to help explain the importance of HPC to funding bodies, key decision makers and the broader public
- IDC will be writing up a number of them for broader dissemination

Example:
Use By Others

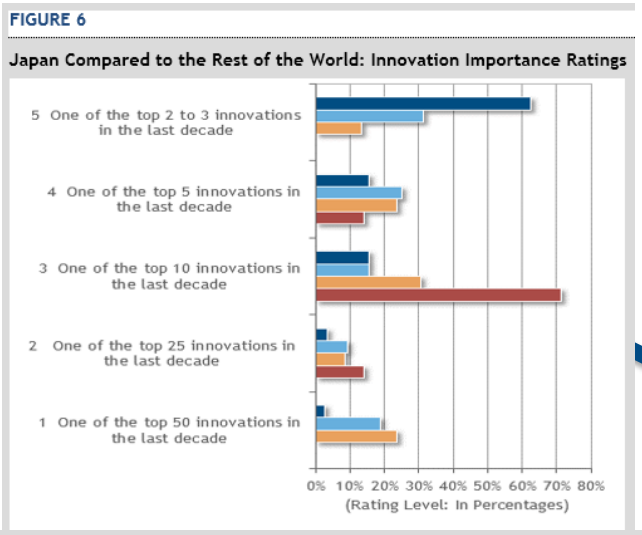
Example of Results Used In Reports/Studies: Blue Waters Assessment Report

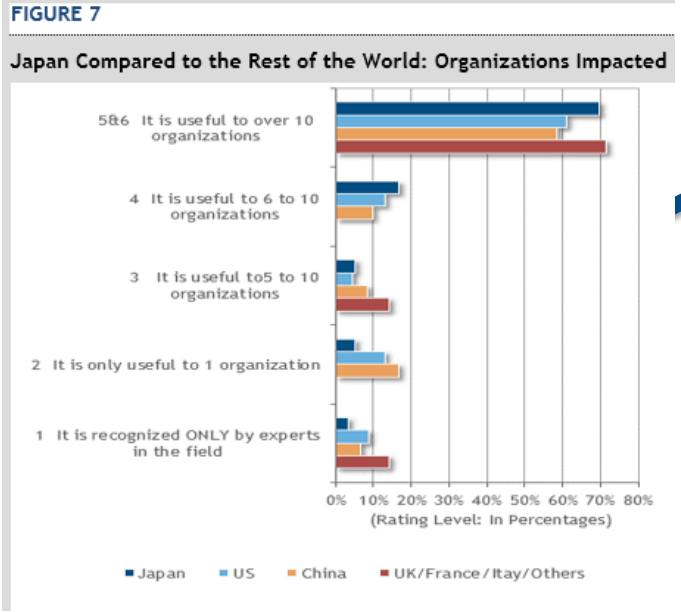


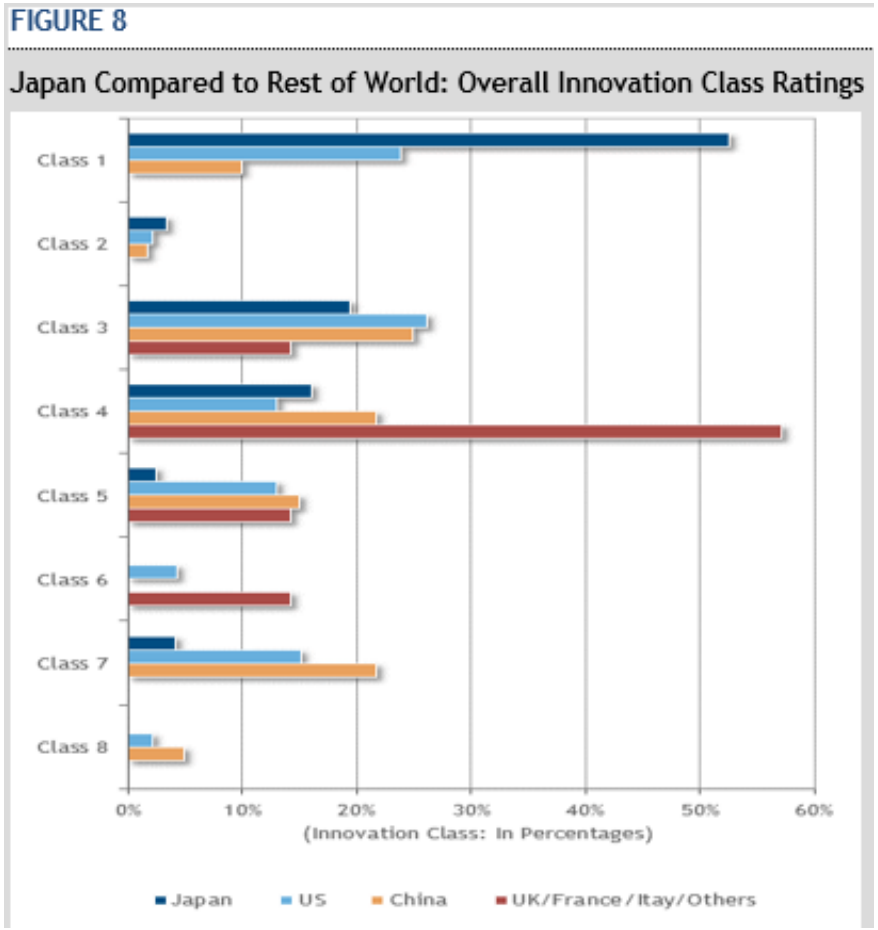




Example of Results Used In Reports/Studies: Riken K-Computer Assessment Report







Publication Plans

We are finally at a stage in the research that we feel comfortable starting the publication process!

Ideas For Future Research

Future Research Ideas

1. **Expand the models to be used as a predictive tool**
   - Forecast the potential value of a new supercomputer (e.g. exascale systems)
   - In both scientific ROR terms and financial ROI terms
   - We tested this on the Post-K computer at Riken

Future Research Ideas

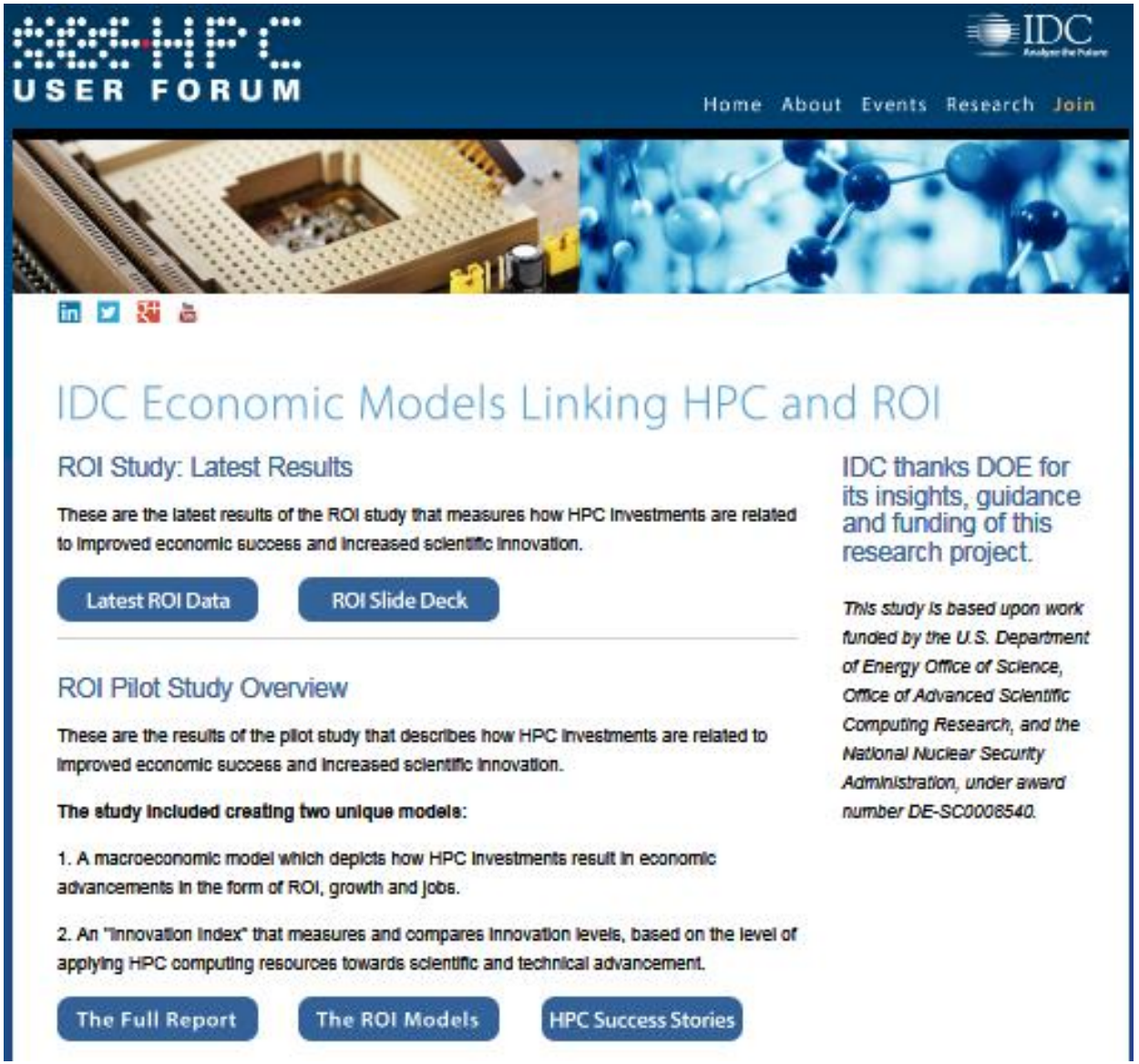
2. **Expand the models to measure the value of an existing HPC system**
   - To show the value of a large supercomputer
   - And perhaps to an existing HPC center
   - We tested this in the Riken study and have a basic approach

Dissemination Program

- **New results, along with the data file are published at: www.hpcuserforum.com/ROI**
- **The pilot report and excel models are also posted at: www.hpcuserforum.com/ROI**
- **IDC sends the new results to ~6,500 people in the broader HPC community**
- **IDC will brief the HPC community at SC16**
  - On Tuesday during the IDC breakfast briefing
  - And at other meetings
- **Does DOE have additional briefings that IDC should conduct?**

IDC Analyze the Future

Web Page: www.hpcuserforum.com/ROI



IDC Analyze the Future

Next Steps: Short Term

Keep pushing to obtain more data points/ROI cases

- With more from Germany, China, France & Japan
- Drive to get better and more complete job creation data

Distribute the results more broadly

- Publish the new results
  - We have started the conversations with key publishers – the goal is publication of the findings in a juried business journal or similar (such as Harvard Business Review)
- More press releases and reach out to business focused groups
  - Now that we have a much stronger data set
- 4 HPC User Forums planned in 2017, plus ISC17 & SC17
- Looking at running a series of ROI success stories with HPCWire

Questions?

Please email:
hpc@idc.com

Or check out:
www.hpcuserforum.com

IDC
Analyze the Future

Back-up Slides

Presentations and Publications

Presentations and Publications

- **HPC Global Trends, meeting presentation, DOD, October 2016**
- **Global HPC Trends, DoD CIO Chief of Analytics, October 2016**
- **HPC Global Trends, meeting presentation, US IC, October 2016**
- **Recent Trends and Changes in the High End of the Supercomputer Market Space, IDC document for clients, September 2016**
- **HPC User Forum talk, HPC and industry, University of Oxford (UK), September 2016**
- **Global HPC Trends, US Army Research Lab in Aberdeen, September, 2016.**
- **Critical HPC Policy Issues, DoD Special Access Program Director, September, 2016**
- **HPC User Forum talk, HPC and industry, Beijing, September 2016**
- **Global HPC Technology Trends and Market Status, Center or the Advanced Study of Languages, University of Maryland, September 2106.**
- **IDC HPC Market Update and New ROI with HPC Results, slides from HPC User Forum, Austin, Texas, YouTube, September 2016**
- **Market Analysis Perspective: Worldwide Technical Computing, 2016. IDC document for clients, August 2016**
- **Status and Prospects for Big data and Cyber security, DoD Army G6 CTO, August 2016.**
- **HPC Technology Trends and Policies, DoD Army Strategic Integration Office, August, 2106.**

Presentations and Publications

- **ISC16 breakfast briefing in Germany, June 2016**
- **ISC European HPC conference, talk on HPC and industry, Frankfurt, Germany, June 2016**
- **Lenovo in Beijing, China, June 2016**
- **Alibaba Cloud in Beijing, China, June 2016**
- **Sugon in Beijing, China, June 2016**
- **Rescale, LLC in San Francisco, California, Spring 2016**
- **Blue Waters Symposium in Sun River, Oregon, Summer 2016**
- **High Performance Computing (HPC): IDC Reports Stunning ROI for Technology, Formtek, June 2016**
- **Statius and Prospects for HPC Technology and Policy, DoD USAF G6 CTO, May 2016.**
- **HPC Policy Study, ITIF Panel Discussion, April 2016**
- **HPC Status Update, High Performance Computing Advisory Committee, Council on Competitiveness, April 2106**
- **IDC Directions in San Jose and Boston, March 2016**
- **HPC Technology and Policy Overview, US Government Client, February 2016**
- **10 Things CIOs Need to Know about High Performance Computing, IDC document for clients, March 2016**
- **HPC Accelerates Innovation for Small and Medium-Size Businesses, IDC document for clients, March 2016**

Presentations and Publications

- **SC annual supercomputing conference, IDC market update presentation, November 2015**
- **Industrial Applications of High Performance Computing: Best Practices (book), eds. A. Osseyran and M. Giles, CRC Press, 2015**
- **IDC FutureScape: Worldwide High Performance Data Analysis 2016 Predictions, IDC document for clients, November 2015**
- **HPC ROI: Invest a Dollar to Make $500-plus Reports IDC, article by John Russell, HPCwire, November 2015**
- **Datanami Subscribers Receive the IDC HPC ROI Research Update, article, Datanami, November 2015**
- **HPC ROI: Invest a Dollar to Make $500-plus Reports IDC, University of Delaware, November 2015**
- **How To Make HPC Happen in Europe, article by Leonardo Flores Anover and Augusto Burgeuno Arjona, Scientific Computing World, October 2015**
- **4 IDC HPC User Forums: Tucson in 2015: Virginia (4/13), Colorado (9/8), Paris (10/12), and Munich (10/15)**
- **IDC Presents an Update on ROI with HPC, insideHPC, September 2015**
- **ISC European HPC conference, talk on HPC and industry, Frankfurt, Germany, June 2015**
- **Applying HPC to Improve Business ROI, Scientific Computing, December 2014**