Special Study

EESI-2 Special Study To Measure And Model How Investments In HPC Can Create Financial ROI And Scientific Innovation In Europe

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IDC OPINION

The use of High Performance Computers (HPC) to generate economic value and scientific innovation has been growing over the last 15 years, and has greatly accelerated since 2009, as countries are looking for ways to get out of the current economic slowdown. Some nations have decided to use HPC as a major competitive advantage to generate growth, stability and economic security.

This is a study that describes and quantifies how HPC investments by governments, industry and academia have historically created economic success and increased the overall scientific innovation capability across Europe. The study created macroeconomic models showing the historic correlations between the use of HPC and the generation of ROI in terms of financial ROI metrics and in terms of scientific innovation. The study included 59 financial ROI projects and 84 scientific innovation projects.

HPC has clearly added great economic value across Europe, and in particular to the organizations included in this study:

- The ROI results were very strong in this study with an average of $867 revenue dollars generated for each dollar invested in HPC in this study.
- The profit ROI average in this study was a healthy $69 dollars in profits (or in cost savings) for each dollar invested in HPC.
- In total, the 59 financial ROI projects generated $184 Billion in combined sales and $12.1 Billion in profits (including cost savings).
- In the survey sample 1,152 new jobs were added at 52 industrial organizations.
- A total of $522 Million was invested to create the 84 scientific innovations in these organizations.
- 12 projects created a scientific innovation that was viewed as one of the top 5 to 25 innovations in their field over the last decade.

In addition, the study results include a large number of HPC success stories.

Note: there is an excel spreadsheet that compliments this report. The spreadsheet includes the raw data and pivot tables to provide easy access and analysis of the data.

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IN THIS STUDY

Why This Research Is Important To Europe

- World scientific leadership and innovation leadership are becoming more dependent on the use of HPC/supercomputers every year
- Economic leadership increasingly directly 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, USA, Japan and other Asian countries)

Methodology: The ROI Models Developed And Used In This Study

1) Financial ROI From HPC Investments

A macroeconomic model which depicts the way HPC investments result in economic advancements in the form of ROI, growth and jobs. This model can be sorted by industry, country, innovation type, organization size, sector, etc.

2) Scientific Innovation ROI From HPC Investments

Two "Innovation Indexes" that provide a means of measuring and comparing innovation levels, based on the level of applying HPC computing resources towards scientific and technical advancement.

Research Approach

This study uses an approach based on traditional business market research methodologies which greatly helps in the required collection of new data points, and provides a faster path to creating the models and results:

- This is different than traditional economic modeling approaches which typically use larger data sets and require a significant amount of time to conduct the analysis and create the models
- The success of this type of research is heavily dependent on the collection of in-depth industrial data around R&D/HPC investments and the resulting business results in revenues and profits

Phase 1: Data Collection

Collection of relevant data from a broad set of resources:

- Collecting mini-case study ROI examples across a broad set of industries, agencies and educational institutions that will inform the development of both the economic model and the innovation index
- The focus of this data collection is to obtain consistent quantitative data

Phase 2: Creation Of The Financial ROI Models

In this phase, IDC developed the macroeconomic models and conducted additional data collection. The models provide a wide-angle macroeconomic view of the ROI chain of interrelationships

- Clearly showing the value of HPC to economic growth

- Data for the models will include specific ROI data on individual products and services that were developed by each company/organization in order to properly correlate it with the specific investments in HPC

Phase 3: Creation Of The Scientific Innovation Indexes

In this phase, IDC created the scientific innovation indexes that identify key metrics of national scientific innovativeness for Europe:

- Based on both existing and new data collected by the study's surveys
- The index variations are shown and by sector and by industry
- Note: There will be two different innovations indexes created as part of this project

Phase 4: The Dissemination Plan

Communicating and disseminating the data, analysis and ideas across the broader European and global HPC communities

- The primary delivery method will be through the EESI-2 report. This includes showing the ROI examples, benefits of HPC, and the potential impacts of expanded HPC investments.
- All communication will be directed by EESI-2
- Note: EESI-2 has full ownership rights for use of the models and data inputs/outputs. IDC also retains ownership rights to the raw data for its use in future studies and/or projects.

EXECUTIVE SUMMARY

Key Findings

Why This Research Is Important To Europe

- World scientific leadership and innovation leadership are becoming more dependent on the use of HPC/supercomputers every year
- Economic leadership increasingly directly 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

The Focus Of This Study

This is a study that describes and quantifies how increases in HPC investments by governments, industry and academia can improve economic success and increase overall scientific innovation capability across Europe. It is a study of the economic value of HPC investments. The study created macroeconomic models showing the correlations between the use of HPC and the generation of ROI in terms of financial ROI metrics and in terms of scientific innovation. The study includes 59 financial ROI projects and 84 scientific innovation projects.

HPC clearly has added great economic value across Europe, and in particular to the organizations included in this study:

- The 59 projects generated $184 Billion in combined sales (similar to GDP) and $12.1 Billion in profits (including cost savings).
- The financial industry generated the largest economic value in the sample at $163.6 Billion in sales and $5.1 Billion in profits (from 26 projects).
- The oil/gas companies in the study generated $12.5 Billion in Sales and $6 Billion in profits from 7 HPC projects.
- The 6 transportation organizations generated $7 Billion in sales and $133 Million in profits.
- In the survey sample 1,152 new jobs were added at the 52 industrial organizations.

The 59 projects generated $184 Billion in sales and $12.1 Billion in profits (including cost savings).

Financial ROI Results: ROI In Sales Revenue

- The ROI results are extremely strong in this study with an average of $867 revenue dollars generated for each dollar invested in HPC in this study.
- The results are even higher when looking at only industrial concerns averaging at $974 revenue dollars generated for each dollar invested in HPC.
- The financial industry has the largest ROI averaging $1,590 revenue dollars generated for each dollar invested in HPC in this study.
- The Transportation industry also has a high rate of return averaging $1,180 revenue dollars generated for each dollar invested in HPC.

Financial ROI Results: ROI In Profits or Cost Savings

- The European average in this study was a very healthy $69 dollars in profits (or in cost savings) for each dollar invested in HPC.
- When looking at only industrial organizations, it was even higher at $75 dollars in profits (or in cost savings) for each dollar invested in HPC.
- The oil/gas industry has the largest profit ROI averaging $267.7 profit dollars generated for each dollar invested in HPC in this study.
- The finance industry also has a high rate of profit return averaging $67 profit dollars generated for each dollar invested in HPC.
- A ten to one return on investment is often considered a great return, so these results are very strong.

The European average was a very healthy $69 dollars in profits (or in cost savings) for each dollar invested in HPC.

Scientific Innovation Results

- In the sample, a total of $522 Million was invested to create the 84 scientific innovations. Note that this excludes the innovations that were part of the 54 financial ROI examples.
- On average, each scientific innovation required an HPC investment of $7.5 Million US dollars. For innovations that created a new approach the HPC investment averaged $10.4 million.
- On average, industrial organizations invested $22.7 Million per scientific innovation, government organizations invested $2.1 Million per innovation and academic sites invested just under $1 Million per scientific innovation.
- 12 projects created a scientific innovation that was viewed as one of the top 5 25 innovations in their field over the last decade.
- 14 of the projects resulted in a scientific innovation that was major and useful to a large number of organizations.
- 23 of the projects provided a scientific innovation that was useful to many organizations.
- And 20 of the scientific innovations were useful to only one organization.

In addition, the study results include a large number of HPC success stories.

12 projects created an innovation that was viewed as one of the top 25 innovations over the last decade.

SITUATION OVERVIEW: THE HPC MARKET IN EUROPE

Introduction

This is a study that describes and quantifies how increases in HPC investments by governments, industry and academia can improve economic success and increase overall scientific innovation capability across Europe.

The study represents a unique and innovative research approach that should provide strong insight to help improve Europe's scientific and economic capabilities.

Project Goals

To create a report for the EESI-2 final deliverables that shows the relationship between investments in HPC and the resulting ROI:

- The data will be based on a deeper collection of examples across Europe, and the report will focus on examples in Europe
- The study will show both ROI in terms of financial results (revenues, profits, cost savings, and job creation); as well as for innovation (basic and applied innovations)

Assess Current Situation: The Global HPC Market

Recent HPC Trends

2013 HPC revenues declined by $800 million, for a total of $10.3 billion in HPC servers sold. Mainly due to a few very large systems sales in 2012, that weren't repeated in 2013. IDC projects healthy growth in 2015 to 2018, although 2014 may be a soft year.

Major trends include:

- Software issues continue to grow
- The worldwide Petascale race is in full speed
- GPUs and accelerators are the hot new technologies
- Big data combined with HPC is creating new solutions in new areas

There are major issues in HPC today -- Software is the #1 roadblock:

- Better management software is needed
- Parallel software is lacking for most users
- Many applications will need a major redesign

Clusters are still hard to use and manage:

- System management & growing cluster complexity
- Power, cooling and floor space are major issues
- Third party software costs
- RAS is a growing issue
- Storage and data management are becoming new bottle necks
- Weak support for heterogeneous environment and accelerators

The global historic HPC market in US dollars (Millions) sold is shown in Table 1. Table 2 shows the number of HPC systems sold each year over the last five years. Table 3 shows the changes in average system prices over the last five years. The global HPC market has experienced healthy growth since the 2008/2009 recession, averaging around 5% yearly growth. It has grown to become over $10 billion a year in yearly purchases.

TABLE 1

IDC HPC Competitive Segments ($US Millions)

Segment	2009	2010	2011	2012	2013	Five Year CAGR
Supercomputer	3,342	3,476	4,370	5,655	3,995	4.6%
Divisional	1,079	1,269	1,237	1,216	1,355	5.9%
Departmental	2,883	3,343	3,467	2,979	3,363	3.9%
Workgroup	1,311	1,411	1,226	1,247	1,586	4.9%
Total	8,614	9,498	10,300	11,098	10,299	4.6%

Source: IDC 2014

The number of HPC systems sold each year has grown from just over 100,000 a year in 2009, to close to 125,000 a year in 2013. The largest HPC systems, supercomputers, has decline in units due to the strong increase in individual supercomputer system prices. Today there are around 1,500 supercomputers being sold each year.

TABLE 2

IDC HPC Competitive Segments (System Sold)

Segment	2009	2010	2011	2012	2013	Five Year CAGR
Supercomputer	2,067	2,560	2,908	2,400	1,484	-7.9%
Divisional	3,596	3,914	3,724	3,663	4,271	4.4%
Departmental	17,963	20,382	20,626	16,981	20,246	3.0%
Workgroup	81,428	92,988	84,295	81,104	97,981	4.7%
Total	105,054	119,844	111,553	104,148	123,982	4.2%

TABLE 2

IDC HPC Competitive Segments (System Sold)

Segment	2009	2010	2011	2012	2013	Five Year CAGR

Source: IDC 2014

Table 3 shows the changes in average selling prices for the overall HPC market and by the four IDC competitive segments. Supercomputers now average just over $2.5 million per system.

TABLE 3

IDC HPC Competitive Segments (Average Selling Prices)

Segment	2009	2010	2011	2012	2013	Five Year CAGR
Supercomputer	1.617	1.358	1.503	2.356	2.691	13.6%
Divisional	0.300	0.324	0.332	0.332	0.317	1.4%
Departmental	0.160	0.164	0.168	0.175	0.166	0.9%
Workgroup	0.016	0.015	0.015	0.015	0.016	0.1%
Total	0.082	0.079	0.092	0.107	0.083	0.3%

Source: IDC 2014

HPC Global Five Year Forecasts

Why HPC is projected to keep growing:

- It has become a competitive weapon
  - For companies, universities and governments
  - Global competitiveness is driving R&D and better product designs
  - Even small companies are using HPC to gain market share
- Governments view HPC leadership as critical
  - For national pride, but more importantly for economic prosperity
  - It use to be 1 large supercomputer – now its multiple ones
- There are very critical HPC issues that need to be solved

- Global warming, alternative energy, safe NE, financial disaster modeling, healthcare, homeland security, …
- And 3D movies and large scale games are fun

- At the same time, “live” science and “live” engineering costs have escalated
  - And time-to-solution is months faster with simulations

Table 4 shows the IDC five forecasts for the global HPC market in US dollars (Millions). IDC is projecting a return to higher growth rates in the 7.6% range over the next five years.

TABLE 4

IDC HPC Market Forecast (US Dollars, Millions)

Segment	2013	2014	2015	2016	2017	Five Year CAGR
Supercomputer	3,995	4,328	4,662	4,995	5,328	7.5%
Divisional	1,355	1,453	1,551	1,649	1,747	6.6%
Departmental	3,363	3,622	3,881	4,140	4,399	6.9%
Workgroup	1,586	1,778	1,970	2,162	2,353	10.4%
Total	10,299	11,181	12,063	12,945	13,828	7.6%

Source: IDC 2014

The Global Broader HPC Market: Five Year Forecasts

Table 5 shows the IDC five forecasts for the global broader HPC market in US dollars (Millions). The "Broader" HPC market includes servers, storage, software and repair services. Overall, the broader HPC market is projected to grow from $20 Billion today, to over $27 Billion by 2017. Storage is expected to grow faster than the other segments.

TABLE 5

IDC HPC Broader Market Forecast (US Dollars, Millions)

Segment	2013	2014	2015	2016	2017	Five Year CAGR
Server	10,299	11,181	12,063	12,945	13,828	7.6%
Storage	3,841	4,279	4,694	5,037	5,531	9.5%

TABLE 5

IDC HPC Broader Market Forecast (US Dollars, Millions)

Segment	2013	2014	2015	2016	2017	Five Year CAGR
Middleware	1,122	1,181	1,285	1,385	1,486	7.3%
Applications	3,305	3,562	3,860	4,207	4,529	8.2%
Repair Services	1,690	1,782	1,850	1,986	2,102	5.6%
Total	20,258	21,986	23,752	25,560	27,475	7.9%

Source: IDC 2014

Assess Current Situation: The HPC Market In Europe

Recent HPC Trends In Europe

The European HPC market has recently started to recover from a low growth rate. Thanks to major European wide initiatives and investments in many different areas of HPC, Europe has returned to be a leader in applying large scale HPC to key scientific and industrial research programs.

At the same time, other nations have also made major advances, especially in Asia and in particular China has shown the highest growth rates.

Why HPC Becoming So Important To Nations

High performance computing (HPC) is important for national economies, because HPC, also called supercomputing, has been firmly linked to economic competitiveness as well as scientific advances. In one worldwide IDC study, 97% of companies that had adopted supercomputing said they could no longer compete or survive without it. As the US Council on Competitiveness puts it: *"To out-compute is to out-compete."*

Worldwide political leaders increasingly recognize this trend:

- In his 2006, State of the Union address, U.S. President George W. Bush promised to trim the federal budget, yet urged more money for supercomputing
- In 2009, Russian President Dmitry Medvedev warned that without more investment in supercomputer technology: *"Russian products will not be competitive or of interest to potential buyers."*
- In June 2010, Rep. Chung Doo-un of South Korea's Grand National Party: "If Korea is to survive in this increasingly competitive world, it must not neglect nurturing the supercomputer industry, which has emerged as a new growth driver in advanced countries."
- In his 2011 State of the Union address, President Obama noted China's rapid progress in HPC

Computational modeling/simulation/design is now established as the third branch of scientific inquiry, complementing theory and experimentation.

HPC-driven innovation has become a prerequisite for:

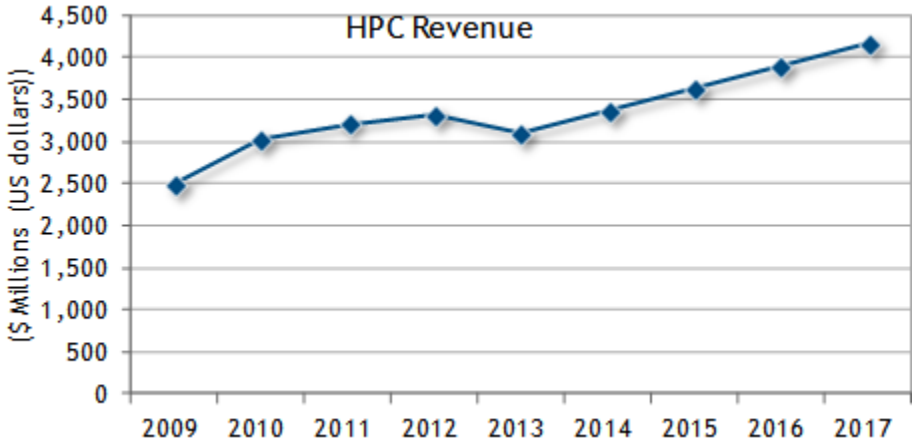
- Scientific leadership
- Industrial leadership
- Economic advancement
- National/regional security

The Overall European HPC Market

Figure 1 and table 6 shows the overall HPC market in Europe. The European market grew well over the last 6 to 7 years, but at a lower rate than the rest of the world. Over the last few years, Europe has been catching up, but with a dip in 2013.

FIGURE 1

European High-Performance Technical Systems: Market Revenues



Source: IDC 2014

The Historic European Market By HPC Segments

Table 6 shows that the supercomputer segment in Europe has been doing well, will the lower portion of the market hasn't been growing as well.

TABLE 6

European HPC Competitive Segments ($US Millions)

Segment	2009	2010	2011	2012	2013	Five Year CAGR
Supercomputer	859	1,152	1,348	1,437	1,323	11.4%
Divisional	313	349	381	430	389	5.6%
Departmental	902	1,053	1,073	1,048	990	2.4%
Workgroup	414	472	409	412	399	-0.9%
Total	2,488	3,027	3,211	3,327	3,102	5.7%

Source: IDC 2014

The Historic European Market By HPC Application/Industry Areas

Table 7 shows the historic HPC market in Europe by different industries and application segments. The high growth segments include:

- Economics/finance/insurance
- Government labs
- Academic/university
- Weather
- EDA/IT

The lower growth segments include:

- Mechanical design (on servers)
- Digital content creation and distribution, animation
- Chemical engineering

TABLE 7

European HPC Market By Application/Industry Areas ($US Millions)

Segment	2009	2010	2011	2012	2013	Five Year CAGR
Bio-Sciences	292	352	366	376	344	4.1%
CAE	308	381	408	430	405	7.1%

TABLE 7

European HPC Market By Application/Industry Areas ($US Millions)

Segment	2009	2010	2011	2012	2013	Five Year CAGR
Chemical Engineering	10	12	13	13	11	1.9%
DCC & Distribution	12	11	12	12	11	-2.0%
Economics/Financial	46	57	74	76	71	11.7%
EDA	81	97	102	105	99	5.1%
Geosciences	259	305	311	327	305	4.2%
Mechanical Design	5	5	5	4	4	-2.1%
Defense	251	301	313	319	297	4.3%
Government Lab	618	775	833	875	829	7.6%
University/Academic	469	564	604	628	585	5.7%
Weather	70	85	90	92	86	5.3%
Other	67	81	80	70	54	-5.4%
EMEA Total	2,488	3,027	3,211	3,327	3,102	5.7%

Source: IDC 2014

The Future European Market By HPC Segments

Table 8 shows the IDC forecast for European HPC purchases, with a very healthy 7.7% yearly growth rate overall and 10.0% growth for supercomputers. The European HPC server market is projected to grow from $3.1 Billion in 2013 to $4.2 Billion in 2017.

TABLE 8

European HPC Market Forecast (US Dollars, Millions)

Segment	2013	2014	2015	2016	2017	Five Year CAGR
Supercomputer	1,323	1,424	1,516	1,560	1,934	10.0%

TABLE 8

European HPC Market Forecast (US Dollars, Millions)

Segment	2013	2014	2015	2016	2017	Five Year CAGR
Divisional	389	429	469	530	505	6.7%
Departmental	990	1,072	1,149	1,249	1,191	4.7%
Workgroup	399	444	500	562	536	7.7%
Total	3,102	3,368	3,635	3,901	4,167	7.7%

Source: IDC 2014

The European Broader HPC Market Segments

Table 9 shows the European broader HPC market growing from $6.2 Billion in 2013 to almost $8 Billion by 2017.

TABLE 9

European HPC Broader Market Forecast (US Dollars, Millions)

Segment	2013	2014	2015	2016	2017	Five Year CAGR
Server	3,102	3,368	3,635	3,901	4,167	7.7%
Storage	1,165	1,279	1,381	1,405	1,443	5.5%
Middleware	355	385	410	412	421	4.4%
Applications	1,040	1,125	1,197	1,200	1,214	4.0%
Service	551	593	628	627	635	3.6%
Total	6,212	6,751	7,250	7,545	7,882	6.1%

Source: IDC 2014

The Historic European Market By Country

Table 10 shows the European HPC market by country for 2009 to 2013. The largest countries, in terms of HPC purchases include Germany, France and the UK.

The higher grow countries include:

- Russia
- Middle East & Africa
- Norway
- Sweden
- Finland
- France

TABLE 10

European HPC Market (US Dollars, Millions): by Country

Country	2009	2010	2011	2012	2013	Five Year CAGR
Denmark	29	38	39	41	38	6.8%
Finland	24	32	33	34	31	7.2%
France	399	509	541	562	525	7.1%
Germany	620	759	809	847	763	5.3%
Italy	236	294	301	303	295	5.7%
Netherlands	52	56	58	60	56	1.9%
Norway	48	65	69	72	67	8.6%
Russia	55	102	133	138	129	23.8%
Spain	115	136	143	147	140	4.9%
Sweden	91	119	127	131	122	7.5%
Switzerland	69	76	81	83	77	2.8%
UK	365	396	401	413	388	1.5%
Central Eastern Europe	134	151	164	171	159	4.5%
Middle East & Africa	113	159	168	175	163	9.6%
Rest of Europe	137	134	144	151	149	2.0%
EMEA Total	2,488	3,027	3,211	3,327	3,102	5.7%

Source: IDC 2014

Table 11 shows the European HPC market by country in percentage of Europe overall.

TABLE 11

European HPC Market (In Percentages): by Country

Country	2009	2010	2011	2012	2013
Denmark	1.2%	1.3%	1.2%	1.2%	1.2%
Finland	1.0%	1.0%	1.0%	1.0%	1.0%
France	16.1%	16.8%	16.9%	16.9%	16.9%
Germany	24.9%	25.1%	25.2%	25.4%	24.6%
Italy	9.5%	9.7%	9.4%	9.1%	9.5%
Netherlands	2.1%	1.9%	1.8%	1.8%	1.8%
Norway	1.9%	2.2%	2.2%	2.2%	2.2%
Russia	2.2%	3.4%	4.1%	4.1%	4.2%
Spain	4.6%	4.5%	4.4%	4.4%	4.5%
Sweden	3.7%	3.9%	3.9%	3.9%	3.9%
Switzerland	2.8%	2.5%	2.5%	2.5%	2.5%
UK	14.7%	13.1%	12.5%	12.4%	12.5%
Central Eastern Europe	5.4%	5.0%	5.1%	5.1%	5.1%
Middle East & Africa	4.6%	5.2%	5.2%	5.3%	5.3%
Rest of Europe	5.5%	4.4%	4.5%	4.5%	4.8%
EMEA Total	100.0%	100.0%	100.0%	100.0%	100.0%

Source: IDC 2014

The Future European HPC Market By Country

Table 12 shows the European HPC market by country for 2013 to 2017. IDC is projecting grow of 6.5% to around 8.0% for the countries in Europe, with an overall grow rate of 7.7%.

TABLE 12

European HPC Forecast (US Dollars, Millions): by Country

Country	2013	2014	2015	2016	2017	Five Year CAGR
Denmark	38	41	44	47	50	7.4%
Finland	31	34	36	39	42	7.4%
France	525	572	619	665	712	7.9%
Germany	763	824	893	973	1,043	8.1%
Italy	295	310	328	355	376	6.3%
Netherlands	56	60	65	70	74	7.4%
Norway	67	72	78	83	89	7.4%
Russia	129	140	152	163	175	7.9%
Spain	140	155	172	176	180	6.6%
Sweden	122	132	142	152	162	7.4%
Switzerland	77	84	90	97	103	7.4%
UK	388	422	457	492	527	8.0%
Central Eastern Europe	159	174	188	202	216	7.9%
Middle East & Africa	163	178	192	207	222	7.9%
Rest of Europe	149	171	178	180	196	7.1%
EMEA Total	3,102	3,368	3,635	3,901	4,167	7.7%

Source: IDC 2014

Table 13 shows the future European HPC market by country, in terms of each country's percentage of Europe.

TABLE 13

European HPC Market Forecast (In Percentages): by Country

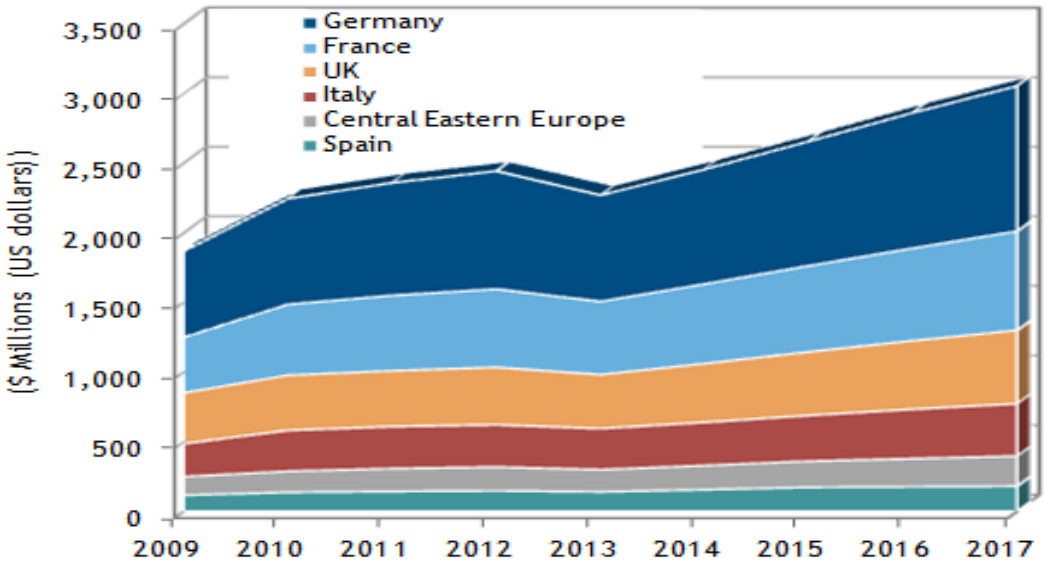
Country	2013	2014	2015	2016	2017
Denmark	1.2%	1.2%	1.2%	1.2%	1.2%
Finland	1.0%	1.0%	1.0%	1.0%	1.0%
France	16.9%	17.0%	17.0%	17.1%	17.1%
Germany	24.6%	24.5%	24.6%	24.9%	25.0%
Italy	9.5%	9.2%	9.0%	9.1%	9.0%
Netherlands	1.8%	1.8%	1.8%	1.8%	1.8%
Norway	2.2%	2.1%	2.1%	2.1%	2.1%
Russia	4.2%	4.2%	4.2%	4.2%	4.2%
Spain	4.5%	4.6%	4.7%	4.5%	4.3%
Sweden	3.9%	3.9%	3.9%	3.9%	3.9%
Switzerland	2.5%	2.5%	2.5%	2.5%	2.5%
UK	12.5%	12.5%	12.6%	12.6%	12.7%
Central Eastern Europe	5.1%	5.2%	5.2%	5.2%	5.2%
Middle East & Africa	5.3%	5.3%	5.3%	5.3%	5.3%
Rest of Europe	4.8%	5.1%	4.9%	4.6%	4.7%
EMEA Total	100.0%	100.0%	100.0%	100.0%	100.0%

Source: IDC 2014

Figure 2 shows the growth trends for the 6 largest countries in Europe (in terms of HPC purchases).

FIGURE 2

European High-Performance Technical Systems: By Largest Countries



Source: IDC 2014

Financial ROI From HPC Investments In Europe

How The Results Are Presented

The financial ROI models that were developed include:

- ROI based on revenues generated (similar to GDP) divided by HPC investment
- ROI based on profits generated (or costs saved) divided by HPC investment
- ROI based on jobs created

The ROI models shown and can be sorted for variances by:

- Industry sector
- Country
- Organization size
- And other attributes

Note: there is an excel spreadsheet that compliments this report. The spreadsheet includes the raw data and pivot tables to provide easy access and analysis of the data.

Financial ROI Results

This study contains 59 real world examples (mini-case studies) of the financial returns from HPC investments made by different organizations across Europe.

A) Financial ROI In Revenues/Sales/GDP

Table 14 shows the overall ROI results for this study. The ROI results are extremely strong in this study with an average of $867 revenue dollars generated for each dollar invested in HPC in this study.

The results are even higher when looking at only industrial concerns averaging at $974 revenue dollars generated for each dollar invested in HPC.

TABLE 14

Financial ROI From HPC Investments In Europe: In Revenues/Sales

Sector	Count	Average Revenue $ per HPC $
Academic	7	$ 30
Industry	52	$ 974
Overall Total	59	$ 867

Source: IDC 2014

Table 15 compares different industries across Europe. The financial industry has the largest ROI averaging $1,590 revenue dollars generated for each dollar invested in HPC in this study.

The Transportation industry also has a high rate of return averaging $1,180 revenue dollars generated for each dollar invested in HPC.

TABLE 15

Financial ROI From HPC Investments In Europe: In Revenues/Sales

By Industry		
Industry	Count	Average Revenue $ per HPC $
Financial	26	$ 1,590
Insurance	1	$ 71
Manufacturing	10	$ 15
O&G	7	$ 312
Research	5	$ 37
Retail	2	$ 25
Telecomm	1	$ 10
Transportation	6	$ 1,180
Environmental Safety	1	$ 30
Overall Total	59	$ 867

Source: IDC 2014

B) Financial ROI In Profits/Cost Savings

Table 16 show the ROI in terms of profits for each HPC investment dollar. The European average in this study was a very healthy $69 dollars in profits (or in cost savings) for each dollar invested in HPC.

When looking at only industrial organizations, it was even higher at $75 dollars in profits (or in cost savings) for each dollar invested in HPC.

A ten to one return on investment is often considered a great return, so these results are very strong.

TABLE 16

Financial ROI From HPC Investments In Europe: Profits or Cost Savings

Sector	Count	Average Profit/Cost Savings in $ per HPC $
Academic	7	$ 29.5
Industry	52	$ 75.0
Overall Total	59	$ 69.3

Source: IDC 2014

Table 17 compares different industries across Europe. The oil/gas industry has the largest profit ROI averaging $267.7 profit dollars generated for each dollar invested in HPC in this study.

The finance industry also has a high rate of profit return averaging $67 profit dollars generated for each dollar invested in HPC.

A ten to one return on investment is often considered a great return, so these results are very strong.

TABLE 17

Financial ROI From HPC Investments In Europe: Profits or Cost Savings

By Industry		
Industry	Count	Average Profit/Cost Savings in $ per HPC $
Financial	26	$ 67.1
Insurance	1	$ 7.1
Manufacturing	10	$ 14.5
O&G	7	$ 267.7
Research	5	$ 36.7
Retail	2	$ 16.1
Telecomm	1	$ 10.0
Transportation	6	$ 17.8
Environmental Safety	1	$ 30.0

TABLE 17

Financial ROI From HPC Investments In Europe: Profits or Cost Savings

By Industry		
Industry	Count	Average Profit/Cost Savings in $ per HPC $
Overall Total	59	$ 69.3

Source: IDC 2014

C) Financial ROI In Job Creation

Tables 18 and 19 show the ROI in terms of job creation. In the survey sample 1,152 new jobs were added at the 52 industrial organizations.

TABLE 18

Financial ROI From HPC Investments In Europe: In Job Creation

Sector	Count	Employee Growth
Academic	7	-
Industry	52	1,152
Overall Total	59	1,152

Source: IDC 2014

TABLE 19

Financial ROI From HPC Investments In Europe: In Job Creation

By Industry		
Industry	Count	Employee Growth
Financial	26	562
Insurance	1	5
Manufacturing	10	93

TABLE 19

Financial ROI From HPC Investments In Europe: In Job Creation

By Industry		
Industry	Count	Employee Growth
O&G	7	48
Research	5	
Retail	2	49
Telecomm	1	210
Transportation	6	185
Environmental Safety	1	
Overall Total	59	1,152

Source: IDC 2014

D) Total Economic Value Created By The 59 Projects In The Study

Table 20 shows the overall economic impact of the 59 ROI examples in this study. The 59 projects generated $184 Billion in sales (similar to GDP) and $12.1 Billion in profits (including cost savings).

The financial industry generated the largest economic value in the sample at $163.6 Billion in sales and $5.1 Billion in profits (from 26 projects).

The oil/gas companies in the study generated $12.5 Billion in Sales and $6 Billion in profits from 7 HPC projects.

The 6 transportation organizations generated $7 Billion in sales and $133 Million in profits.

TABLE 20

Total HPC Returns From The 59 ROI Examples

By Industry			
Industry	Number of Organizations	Revenues/Sales	Profits (or Cost Saving)
Financial	26	$ 163,617	$ 5,134
Insurance	1	$ 63	$ 6

TABLE 20

Total HPC Returns From The 59 ROI Examples

By Industry			
Industry	Number of Organizations	Revenues/Sales	Profits (or Cost Saving)
Manufacturing	10	$ 1,050	$ 435
O&G	7	$ 12,545	$ 5,997
Research	5	$ 12	$ 12
Retail	2	$ 135	$ 105
Telecomm	1	$ 375	$ 375
Transportation	6	$ 7,011	$ 133
Environmental Safety	1	$ 3	$ 3
Overall Total	59	$ 184,810	$ 12,199

Source: IDC 2014

E) Financial ROI Based On the Type Of Industrial Innovation

Table 21 shows the 59 financial ROI projects by the different types of innovations. 28 projects created a new approach, and 22 innovations were around creating better products.

TABLE 21

Industrial Innovation ROI From HPC Investments

For The 59 Projects With a Financial ROI			
Primary Innovation / ROI Area	Count	Average Amount Of HPC $M per Innovation	Total HPC Investment
Created New Approach	28	$ 4.74	$ 99.95
Better Products	22	$ 149.48	$1,779.40
Discovered Something New	4		$ 0.19
Cost Saving	2	$ 1.75	$ 1.93
Helped Society	2	$ 0.45	$ 0.50

TABLE 21

Industrial Innovation ROI From HPC Investments

For The 59 Projects With a Financial ROI			
Primary Innovation / ROI Area	Count	Average Amount Of HPC $M per Innovation	Total HPC Investment
Helped Research Program	1	$ 8.50	$ 8.50
Grand Total	59	$ 80.39	$1,890.46

Source: IDC 2014

Scientific Innovation From HPC Investments In Europe

This study contains 84 real world examples (mini-case studies) of innovations from HPC investments made by different organizations across Europe.

How The Results Are Presented

The Innovations are divided into 7 types:

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

Two Different Scientific Innovation Indexes Were Created

Scale One: Importance of the Innovation

How would you rate this innovation compared to all other innovations in this field over the last ten years?

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

Scale Two: Number of Organizations Impacted

How would you rate this innovation compared to all other innovations in this field over the last ten years?

5 = It had a major impact and is useful to many organizations

4 = A minor innovation that is useful to many organizations

3 = A minor innovation only useful to 2 -3 organizations

2 = A minor innovation only useful to 1 organization

1 = An innovation that is recognized ONLY by experts in the field

Scientific Innovation Results

A) Innovation Results: Scientific Innovations Based On the Type Of Innovation

Table 22 shows the 84 scientific innovations by the different types of innovations. In the sample, a total of $522 Million was invested to create the 84 scientific innovations. Note that this excludes the innovations that were part of the 54 financial ROI examples.

On average, each scientific innovation required an HPC investment of $7.5 Million US dollars. For innovations that created a new approach the HPC investment averaged $10.4 million.

TABLE 22

Scientific Innovation ROI From HPC Investments

For The 84 Projects That Created An Innovation			
Primary Innovation / ROI Area	Count	Average Amount Of HPC $M per Innovation	Total HPC Investment
Created New Approach	43	$ 10.39	$ 405.07
Better Products	18	$ 5.96	$ 71.49
Discovered Something New	9	$ 0.89	$ 6.25
Cost Saving	8	$ 3.94	$ 23.65
Helped Society	5	$ 2.40	$ 9.61
Helped Research Program	1	$ 6.25	$ 6.25
Grand Total	84	$ 7.57	$ 522.31

Source: IDC 2014

B) Scientific Innovation: Innovation Index "One"

Table 23 and Figure 3 show the 12 scientific innovations using the importance scale index. Most organizations used the middle three levels, and none used the highest level.

12 projects created a scientific innovation that was viewed as one of the top 5 to 25 innovations in their field over the last decade.

TABLE 23

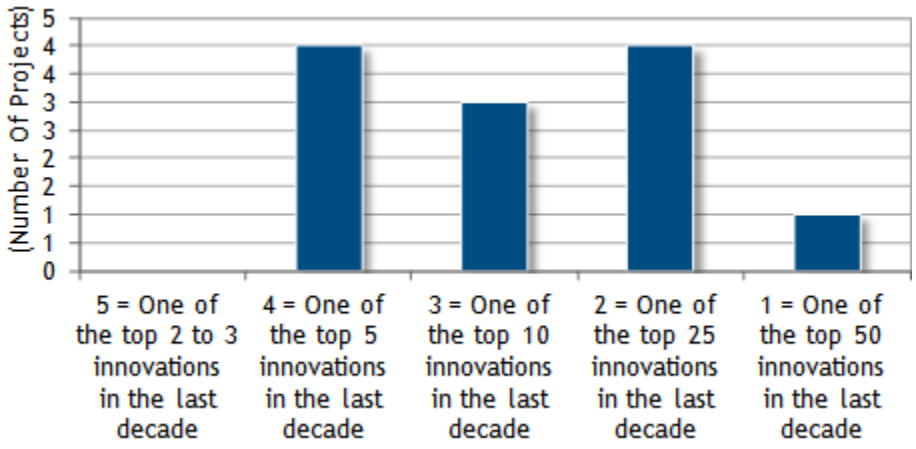
The Innovation Index 1: Importance Of The Innovation

	Count	Percentage Of Sample
5 = One of the top 2 to 3 innovations in the last decade	0	0.0%
4 = One of the top 5 innovations in the last decade	4	22.2%
3 = One of the top 10 innovations in the last decade	3	16.7%
2 = One of the top 25 innovations in the last decade	4	22.2%
1 = One of the top 50 innovations in the last decade	1	5.6%
Total	12	

Source: IDC 2014

FIGURE 3

The Innovation Index 1: Importance Of The Innovation



Source: IDC 2014

C) Scientific Innovation: Innovation Index "Two"

Table 24 and Figure 4 show the scientific index for the range of organizations impacted by the innovation. The 72 projects were fairly evenly spread across the scale, expect only 1 rated it as "an innovation that is recognized ONLY by experts in the field."

14 of the projects resulted in a scientific innovation that was major and useful to a large number of organizations.

23 of the projects provided a scientific innovation that was useful to many organizations.

And 20 of the scientific innovations were useful to only one organization.

TABLE 24

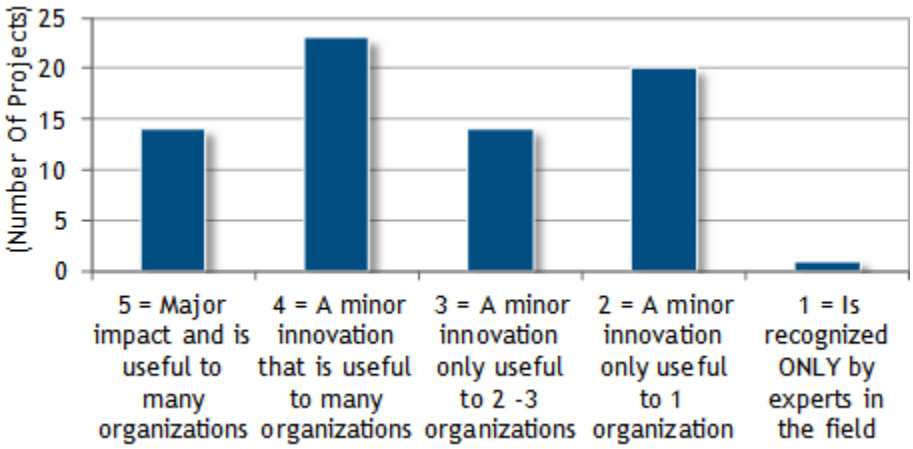
The Innovation Index 2: Number Of Organizations Impacted By The Innovation

	Count	Percentage Of Sample
5 = It had a major impact and is useful to many organizations	14	16.5%
4 = A minor innovation that is useful to many organizations	23	27.1%
3 = A minor innovation only useful to 2 -3 organizations	14	16.5%
2 = A minor innovation only useful to 1 organization	20	23.5%
1 = An innovation that is recognized ONLY by experts in the field	1	1.2%
Total	72	

Source: IDC 2014

FIGURE 4

The Innovation Index 1: Importance Of The Innovation



Source: IDC 2014

D) Basic vs. Applied Innovations In The Study

Table 25 shows the ratio of basic and applied scientific innovations in the study. There were 50 basic innovations and 34 applied research innovations.

TABLE 25

Basic vs. Applied Innovations

Sector	Count of Basic	Count of Applied
Academic	42	8
Government	2	2
Industry	6	24
Grand Total	50	34

Source: IDC 2014

Table 26 shows the average HPC investments for scientific innovations by sector. On average, industrial organizations invested $22.7 Million per scientific innovation, government organizations invested $2.1 Million per innovation and academic sites invested just under $1 Million per scientific innovation.

TABLE 26

Average HPC Investment Per Innovation

Sector	Average HPC $M per Innovation
Academic	$ 0.91
Government	$ 2.11
Industry	$ 22.69
Grand Total	$ 7.57

Source: IDC 2014

Additional Findings From The Study

The study results include a large number of HPC success stories

Short summaries of the 59 financial ROI examples and the 84 innovation examples are listed in the Appendix.

CONCLUSIONS AND CAUTIONS

Key Observations

Macroeconomic models can be very useful in helping to better understand the relationships between investments and outcomes. They can be used to help direct future investments into areas that provide higher returns and greater innovation. At the same time, one has to be very careful about using the models and ensure that there is both enough data in the models and that the models apply to the specific decision being made.

This is a study that describes and quantifies how HPC investments by governments, industry and academia have historically created economic success and increased the overall scientific innovation capability across Europe.

HPC has clearly added great economic value across Europe, and in particular to the organizations included in this study:

- The ROI results were extremely strong in this study with an average of $867 revenue dollars generated for each dollar invested in HPC in this study.
- The profit ROI average in this study was a very healthy $69 dollars in profits (or in cost savings) for each dollar invested in HPC.
- In total, the 59 financial ROI projects generated $184 Billion in combined sales (similar to GDP) and $12.1 Billion in profits (including cost savings).
- In the survey sample 1,152 new jobs were added at 52 industrial organizations.
- A total of $522 Million was invested to create the 84 scientific innovations. On average, each scientific innovation required an HPC investment of $7.5 Million US dollars.
- 12 projects created a scientific innovation that was viewed as one of the top 5 to 25 innovations in their field over the last decade.

Areas To Be Cautious About When Using The Research Findings

This is an exploratory study of the economic and scientific impacts of investments in HPC. It is based on a collection of success stories, and doesn't include projects that didn't result in a success. So for making major investment decisions, one needs to account for projects that didn't generate economic or scientific results.

The research is also based on historic correlations, which can be good for showing relationships, but can also be misleading. IDC plans to conduct future research in this area to develop economic models that measure and show the causal relationships between investments in HPC and the resulting ROI.

LEARN MORE

Related Research

Additional research from IDC in the technical computing hardware program includes the following documents:

- Worldwide Technical Computing Server 2014-2018 Forecast May 2014 Doc #248779 Chirag Dekate, Ph.D., Earl C. Joseph, Ph.D., Steve Conway
- Perspectives on High-Performance Data Analysis: The Life Sciences May 2014 Doc #248348 Update Steve Conway, Chirag Dekate, Ph.D., Earl C. Joseph, Ph.D.
- Global HPC Market Dynamics in 2013 Apr 2014 Doc #248137 Chirag Dekate, Ph.D., Earl C. Joseph, Ph.D., Steve Conway
- Industrial Partnership Programs and High-Performance Computing: HPC User Forum, April 7-9, 2014, Santa Fe, New Mexico Apr 2014 Doc #248113 Earl C. Joseph, Ph.D., Steve Conway, Chirag Dekate, Ph.D.
- International Perspectives on Industrial High-Performance Computing Partnerships: HPC User Forum, April 7-9, 2014, Santa Fe, New Mexico Apr 2014 Doc #248122 Steve Conway, Earl C. Joseph, Ph.D., Chirag Dekate, Ph.D.
- Worldwide HPC Public Cloud Computing 2014-2017 Forecast Apr 2014 Doc #247846 Chirag Dekate, Ph.D., Earl C. Joseph, Ph.D., Steve Conway
- IDC's Worldwide High-Performance Computing Predictions 2014 Feb 2014 Doc # WC20140211 Earl C. Joseph, Ph.D., Chirag Dekate, Ph.D., Steve Conway
- Market Analysis Perspective: Worldwide HPC, 2013 — Directions, Trends, and Customer Requirements Dec 2013 Doc # 244742 Earl C. Joseph, Ph.D., Steve Conway, Chirag Dekate, Ph.D.
- China Eyes 10,000-Fold Data Reduction for Internet of Things Oct 2013 Doc #IcUS24392513 Steve Conway
- National and International Initiatives: HPC User Forum, September 2013, Boston, Massachusetts Oct 2013 Doc # 243776 Steve Conway, Chirag Dekate, Ph.D., Earl C. Joseph, Ph.D.
- Chinese Research in Processor Designs for High-Performance Computing and Other Uses Oct 2013 Doc # 243502 Chirag Dekate, Ph.D., Steve Conway, Earl C. Joseph, Ph.D.
- The Broader HPC Market 2012-2017 Forecast: Servers, Storage, Software, Middleware, and Services Aug 2013 Doc #242742 Earl C. Joseph, Ph.D., Chirag Dekate, Ph.D., Steve Conway
- IDC's Worldwide Technical Server Taxonomy, 2013 Aug 2013 Doc # 242725 Chirag Dekate, Ph.D., Earl C. Joseph, Ph.D., Steve Conway
- China Regains Top Supercomputer Title Jun 2013 Doc #IcUS24190613 Earl C. Joseph, Ph.D., Steve Conway

Appendix: Short Descriptions Of the ROI Projects

TABLE 27

Short Descriptions of the ROI Examples in the Study

Innovation ROI Examples	Financial ROI Examples
HPC Tools for unsteady combustion simulations in real systems	CFD based Light Aircraft Design for Energy Efficient Flight
Improved Aerodynamic simulation fidelity	Maximizing oil reservoir production
Maximizing oil reservoir production	Electro-plating for processor development
Electro-plating for processor development	Automated under hood thermal management of CFD workflow
Computational Statistical analysis of Sporting Events	Depth Imaging on Block 32 in the Gulf of Guinea
Multi-scale CFD for Fluid Catalytic Cracking	10x improvement in Seismic Visualizations
Depth Imaging on Block 32 in the Gulf of Guinea	Speed of Materials Science Simulations
Laminar Turbulent transition simulations of Combustion	Usability of Oceanography Code Enhanced
Enabled 30-year econometric simulations	Atmospheric Chemistry Simulations Enhanced
Enabling new medical applications using HPC	Step Change in Turbulent Combustion Simulation
CFD based Light Aircraft Design	Speed of Materials Science Code Quadrupled
Open Water Analysis	$3M Savings - Quantum Montecarlo Simulations
Brain analysis using HPC	Computationally driven Economic Monitor
Heart Modelling Application 20x Faster	$875M in healthcare insurance analytics
Speed of Materials Science Simulations	Innovative Engineering in Race Car Design
Simulation based blood supply management	$200M revenue through improved insurance simulations
Geodynamic Thermal Convection Simulations Enhanced	Innovative Engineering in Plastics Manufacturing
Usability of Oceanography Code Enhanced	Consumer purchase data analytics
Atmospheric Chemistry Simulations Enhanced	Design and Building of Aerospace Systems
Step Change in Turbulent Combustion Simulation	Travel logistics operational management
Oceanography Code (NEMO) Enhanced	Project Grid Support
Innovative stream computing for econometrics	Analyzing seismic profiles of a region of the Gulf of Mexico

TABLE 27

Short Descriptions of the ROI Examples in the Study

Innovation ROI Examples	Financial ROI Examples
Performance of Molecular Dynamics Application 20x	Improved back office processing time
Faster Higher Fidelity Gyrokinetic Plasma Turbulence Simulations	SAAS and IAAS using HPC
Turbulent Fluid Flow Simulations	Disaster modeling and insurance analytics
Fluid Turbulence Simulations Enhanced up to 40x	$17.5M revenue through insurance analytics
Aeroacoustics and Geophysical Fluid Dynamics Solvers	$1.54B through debt analytics simulation improvement
Magnetic Plasma Turbulence Modeling Code	$370M revenue through improved financial analytics
Turbulent Fluid Flow Simulations Improved	$17.5M revenue through insurance analytics
Simulations of Catalytic Chemistry 8x Faster	$185M through realtime investment decisions
Speed and Scalability of Key Materials Science Code	$1.75B through enhanced financial analytics
Massive Remote Batch Visualizations	$175M through high performance financial analytics
Materials Science Code Enhanced	$17.5B through integrated analytics
Materials Science Codes (CASTEP, ONETEP) Enhanced	$17.5B through consolidation analytics
HELIUM Code Enhanced	$3.75M through financial data analytics
Molecular Dynamics Code Enhanced	$17.5 revenue through enhanced financial analytics
RMT Method for Schrödinger Equation Solutions	$1.75M revenue through simulations
Multi-Phase CFD Code (Fluidity)	$375M through improved performance in finance
Electron-Molecule Scattering	$8.5M through innovative Financial Infrastructure
Multi-Phase CFD Code Developed	$62.5M in catastrophic risk analytics
Identified Sodium Nitrites Role in Causing Cancer	HPC for pricing comparison data
VASP Materials Science Code Optimized	HPC driven design and building of safety systems
CRYSTAL Materials Modeling Code Enhanced	$6.5M profits through financial systems improvements
Scalability and Efficiency of Navier-Stokes Codes	$82.5M through integrated financial analytics
Materials Science Code (CONQUEST)	$67.5 through retail analytics

TABLE 27

Short Descriptions of the ROI Examples in the Study

Innovation ROI Examples	Financial ROI Examples
Improved I/O for larger voxel-based simulations	$375M from pricing and tariff analytics
Turbulent Fluid Flow Simulations Improved by 6x	$1.54B through improved financial analytics
Aeroacoustics and Geophysical Fluid Dynamics Solvers	$37.5M through booking systems optimizations
Quantum Mechanical simulation package	$100M through advanced Market Intelligence
Magnetic Modelling Code (MICROMAG) Parallelized	HPC driven insurance operations
Speed of Materials Science Code Quadrupled	HPC driven insurance quotes
Computational Fluid Dynamics Solver	Data Mapping and Consolidation using HPC
$3M Savings - Quantum Montecarlo Simulations	Computational Ledger Implementation
innovative framework for HPC Dissemination	Trade analytics to identify abnormal activity
Targeted Drug Delivery	HPC driven underwriting of insurance quotes
100% CFD designed rocket car	Real time stock records
3d modelling of porus media	$67.5M through transportation analytics
Computational analysis of liver damage due to alcohol	Simulation driven reduction of engine emissions
Innovative Financial Analytics Simulations	$4.62B through transportation analytics
Geological simulations for City Planning	
Improving Accuracy of Weather Forecasts	
Simulation driven city planning and improvement	
Understanding Mechanisms leading to Drug Resistance	
Improved webprofiling analytics	
Analytics for new asthma product	
$875M in healthcare insurance analytics	
Improved data intensive financial analytics	
Innovative fund management simulations	

TABLE 27

Short Descriptions of the ROI Examples in the Study

Innovation ROI Examples	Financial ROI Examples
Stabilizing Flows In Oil Reservoirs	
Improving Materials in Gas Cylinders	
Realistic Architectural Immersive Simulation	
Technical Computing Software for Modeling and Analysis of Buildings	
Reducing Turnaround of Stability Tests	
Innovative systems for financial simulations	
Innovative Engineering in Race Car Design	
1.26% efficiency improvements in wind turbine	
$200M revenue through improved insurance simulations	
Innovative simulations to enhance bottle manufacturing	
Innovative Engineering in Plastics Manufacturing	
Developing New Catalysts for Fuel Cells	
Process optimization and stamping tools	
Simulation driven multi-cylinder piston engines design	
4% improved Wing Lift Aerospace	
Accelerated Car Design and Development	

Source: IDC 2014

About IDC

International Data Corporation (IDC) is the premier global provider of market intelligence, advisory services, and events for the information technology, telecommunications and consumer technology markets. IDC helps IT professionals, business executives, and the investment community make fact-based decisions on technology purchases and business strategy. More than 1,100 IDC analysts provide global, regional, and local expertise on technology and industry opportunities and trends in over 110 countries worldwide. For 50 years, IDC has provided strategic insights to help our clients achieve their key business objectives. IDC is a subsidiary of IDG, the world's leading technology media, research, and events company.

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