Comments on Return on Investment for Academic Research Computing and Data Support

How to define, measure, and report return on investment information for research computing & data that is meaningful to your organization and to national and international scale computational and research data needs

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Outline of talk

ROI in Research Computing and Data Delivery Settings
Defining return for your organization, region, or project
  • Financial aspects
  • Non-financial modes of return
Defining investment
  • Monetary - personnel, hardware, and operations costs
  • Organizational factors
Comparing ROI for different approaches and large-scale projects
Some comments toward the future
Takeaway to set expectations:

Some academic organizations still consider research computing and data resources as cost centers, taking resources away from the academic mission.

Our research* clearly indicates that in most cases, they are more accurately represented in financial terms as profit/productivity centers, and play an essential role in non-financial academic and research productivity.

We need to consider what this means when funding national and international-scale academic research.

* (References cited below.)
“Show me your budget, and I’ll tell you what you value.”

Senator Joe Biden, Sept. 15, 2008
ROI Simplified

Determine and measure what you VALUE.

Characterize and quantify your INVESTMENTS.

ROI numerically is the ratio of your return to what you invest, and qualitatively what you gain in value compared to expense.
The diagram illustrates the relationship between cost centers and various metrics of research success. It highlights that cost centers should be reevaluated to ensure they support the broader goals of research, including:

- Research income
- Discovery
- Impact
- Innovation
- Academic output
- Community
- Learning
- Awards & recognition
- Productivity
- Products
- Patents
- Training
Definition of “Return”

Simplest quantifiable numerical form: Financial aspects

While simple to define, such metrics vary depending on what you want to measure:

- **Raw value** of externally funded research supported
- **F&A / indirect costs** obtained through such research
- **Charges to users** for access to research computing and data infrastructure
- **Cost avoidance** compared to other methods of resource or service delivery
- This is an easy set of numbers for you to gather for each method of delivery!
- Despite the simplicity, relatively few institutions gather or aggregate such statistics on any level, and even fewer report these to upper administration.
## Examples of Financial ROI factors

**Stewart et al., PEARC19, https://doi.org/10.1145/3332186.3332228**

<table>
<thead>
<tr>
<th>Area of Benefit</th>
<th>Measure of Benefit</th>
<th>Ways to Measure Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct grant income</td>
<td>Monetary income from grants and F&amp;A</td>
<td>Measure income attributable to use of the resources</td>
</tr>
<tr>
<td>Products &amp; patents</td>
<td>Monetary income from licenses and spinoffs</td>
<td>Allocate part of income attributable to use of resources</td>
</tr>
<tr>
<td>Economic impact</td>
<td>Regional economic impact as measured by economic models (IMPLAN)</td>
<td>Indirect financial benefits, jobs, &amp; tax income attributable to existence of resources</td>
</tr>
<tr>
<td>Productivity of end users of CI facilities in research</td>
<td>Financial value of time saved</td>
<td>Cost of the time that would have been spent by end user doing research without use of CI resources</td>
</tr>
<tr>
<td>Cost avoidance for CI resource delivery</td>
<td>Value of investment in other CI facilities that would have been made without use of a particular facility</td>
<td>Actual costs, cost avoidance</td>
</tr>
<tr>
<td>Cost avoidance though personnel resources</td>
<td>Value of support and consulting from CI resource provider</td>
<td>Evaluate allocated usage as a fraction of total costs for providing support and consulting</td>
</tr>
<tr>
<td>Training improvement value</td>
<td>Value of training materials created by organizations operating CI facilities &amp; knowledge gained by users</td>
<td>Perceived value, equivalent cost of commercial training, value of CI skills held by employee entering job market</td>
</tr>
</tbody>
</table>
Definition of “Return”
Non-financial quantitative aspects and qualitative considerations

Most organizations place definite value on factors other than dollars received:

- Publications and academic output
- Training and instruction to students, staff, & faculty
- Recruitment and retention of forefront researchers
- Familiarity with computational and data science research methods
- Speed to research output
- Prestige of the organization in tackling forefront and societally valuable topics

- Important aspects of return must be defined in the context of your organization!
## Examples of Quantifiable Non-financial ROI

Stewart et al., PEARC19, [https://doi.org/10.1145/3355738.3355749](https://doi.org/10.1145/3355738.3355749)

<table>
<thead>
<tr>
<th>Output</th>
<th>Outcome</th>
<th>Nonfinancial measures of outcome</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>New discoveries reported in publications</td>
<td>Publications</td>
<td>Number of publications, citations of publications, impact factors of publications (and the journals in which publications appear)</td>
<td>Improved quality of life for people</td>
</tr>
<tr>
<td>Productivity</td>
<td>Shorter time to publications</td>
<td>Time saved</td>
<td>Better management of natural and personnel resources</td>
</tr>
<tr>
<td>People trained in areas in which they would otherwise not have been trained</td>
<td>A better-trained STEM workforce</td>
<td>Increased salary, greater employment security for the individual</td>
<td>A better-trained workforce for the economy; Improved global competitiveness for any given country</td>
</tr>
<tr>
<td>Awards, press notices</td>
<td>Any award, e.g., Nobel Prize</td>
<td>Numbers, types of awards</td>
<td>Recognition of a particular invention’s significance; reputational benefits for the people and organizations winning the award</td>
</tr>
<tr>
<td>Patents and licenses</td>
<td>An invention is legally protected by exclusive use of the patent holder or licensee</td>
<td>Number of patents</td>
<td>The invention may become a commercial product, or may be used in commercial products that improve people’s quality of life, and the sustainability of human life on Earth</td>
</tr>
</tbody>
</table>
Definition of “Investment”

Monetary - hardware, operations costs, and personnel

To understand your institution’s investment in providing access to research computing and data resources requires a comprehensive view:

• Personnel costs for professional staff including consulting and support
• Differential cost to provide physical space, equipment, and other hardware capital investments
• Electrical power, cooling, and maintenance for on-premises equipment
• Contracting costs for externally provided cycles and storage
• Administrative expenses, including procurement and contract management
• Investment in outreach related to broadening diversity of participant cohort
## Examples of investment factors

**Monetary - hardware, operations costs, and personnel**

<table>
<thead>
<tr>
<th>Area of Expense</th>
<th>Purpose of Expense</th>
<th>Ways to Measure Investment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct personnel costs</td>
<td>Support researchers using resources</td>
<td>Salary and benefits (if internal), contracts (if external)</td>
</tr>
<tr>
<td>Hardware acquisition</td>
<td>Computational and/or storage resources</td>
<td>Cost to purchase amortized over useful lifetime</td>
</tr>
<tr>
<td>External/cloud resources</td>
<td>Computational and/or storage resources</td>
<td>Annual cost of contract and any applicable overage</td>
</tr>
<tr>
<td>Maintenance costs</td>
<td>Service contracts or repair and replacement of on-site equipment</td>
<td>Costs of contracts or unscheduled maintenance</td>
</tr>
<tr>
<td>Electricity and cooling</td>
<td>Direct power to on-site equipment including power needed to provide cooling</td>
<td>Cost of electricity used and facility cost for cooling</td>
</tr>
<tr>
<td>Data ingress/egress fees</td>
<td>Most applicable to off-site (cloud) resources</td>
<td>Annual cost of contract and any applicable overage</td>
</tr>
<tr>
<td>Machine room space</td>
<td>Provide physical location for on-site resources</td>
<td>Differential cost compared to use of that space for other institutional purposes</td>
</tr>
<tr>
<td>Software</td>
<td>Software to run on either on-site or off-site resources, as well as to retrieve and analyze results</td>
<td>Licensing costs, personnel support for either on-site or off-site usage, cost avoidance compared to other tools</td>
</tr>
<tr>
<td>Training</td>
<td>Reduce time cost to researchers and/or support staff to use or provide access to resources</td>
<td>Direct cost of externally contracted training, portion of staff time devoted to delivering or receiving training</td>
</tr>
</tbody>
</table>
Definition of “Investment”

Organizational factors

The exact nature of investment on the part of the institution may and usually does extend far beyond the raw cost of investing in on-premises equipment or cloud contracts.

- Providing the basic resources to be used by researchers
- Creating proper conditions for researchers to be productive
- Providing adequately robust, backed-up locations for data storage
- Investing in personnel training to provide support staff
- Tuning delivery of resources to institution’s population and fields of interest
- Promoting and encouraging use of modern, efficient, up-to-date methods
- Making use of national and international resources beyond your institution
Comparing ROI for different approaches

If you don’t measure ROI, you have no basis for comparison!

In the above summary, supported by research and confirmed by the CASC-sponsored open community Cloud and Data Center Usage Surveys* (next slides), we can see that there are many factors that enter into the definition of both the numerator (return) and denominator (investment) of the ROI equation.

Both financial and on-financial aspects of return on investment need to be considered.

The exact formulation of the factors for these comparisons will vary greatly among institutions, and the relative weights and importance will also vary.

Most organizations that undertake this effort find a positive ROI for use of advanced research computing and data resources, and a positive impact on their institutions.*

* Chalker et al., PEARC20, https://doi.org/10.1145/3311790.3396642
CASC ROI Surveys 2019/2020

Some conclusions from PEARC’20 paper attached:

CASC conducted two surveys on these topics. Here are some important results:

• Only a small fraction (25-30%) of institutions reported measuring or reporting ROI to their upper administration on a regular basis.

• Only a small fraction of institutions have explored cloud for large-scale usage.

• Large-scale institutions more likely to have tested commercial cloud usage for production, but did not report cost savings for bulk computing tasks.

• Definite use cases exist for commercial cloud usage, but these are so far mostly not driven by cost considerations.

• Tradeoffs between the factors described in the paper have yet to be explored.

• A new survey based on the above is in progress now.
ROI Conclusions So Far

Here are the basic conclusions from the work presented so far:

• Factors entering into both the numerator and denominator for ROI vary by institution, and need to be considered across a broad range.

• So far, in two surveys, only a small fraction of institutions regularly gather and report ROI information.*

• Most institutions that measure ROI find a positive story to tell.*

• A complete approach is to measure ROI including all appropriate factors for different forms of delivery, including on-premises, off-premises commercial cloud, and access to national-scale competitive and cooperative resources for your researchers and institution, to be able to compare relative effectiveness.

* For details see attached paper and references
Factors for Large-Scale Research Computing

In our settings, providing research computing and data support necessarily has to span a large range of service types and delivery to serve a very large array of needs.

• Grids still exist and provide extraordinarily good return on investment for their established community users (cf: https://opensciencegrid.org, https://egi.eu, etc.)

• A wide variety of commercial cloud use cases has already arisen in research computing and data settings in which extra expense of such delivery mechanisms is not the predominant factor, and funding agencies have delivered mechanisms to explore these use cases. Comprehensive efforts to optimize ROI in such settings are only beginning.

• Europe and the US notably diverge strongly in the organization of funding opportunities to support and make use of coherent science grids and clouds.

• No comprehensive attempt has been made to site US national supercomputing facilities at locations that could make use of renewable energy to lower electricity costs and reduce greenhouse gas emission consequences of large scale science computation.
Example: Open Science Grid, March 2021

OSG service delivery exceeds 170M cpu hours/month (NSF CC* institutions: ~24M cpu hours/month)

- OSG focus on high throughput computing still meets the needs of many science & engineering communities.
- Has developed connectors for bursting into the commercial cloud for specific reasons (GPUs, etc.)
- Service delivery yields ~O($100M) per year worth of computing for a small fraction of the comparative costs if purchased at commercial rates.
- Not yet comparable to EOSC/EGI in terms of range, variety, and sophistication of delivery models.
EGI-ACE Project and Transition To EOSC

Total grid service delivery exceeds 600M cpu hours/month

- EGI-ACE now one of a large number of grid, cloud, and distributed computing projects in Europe spanning a very large number of specific fields, service delivery modes, and levels of research and business community engagement.

- High energy physics / WLCG accounts for most of the US service delivery shown here.

- Total EGI service delivery yields ~O($300M)/year worth of computing for a small fraction of the comparative costs if purchased at commercial rates.

- European Open Science Cloud (EOSC) is a much larger multi-project effort too large to summarize here.
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European Open Science Cloud

A comprehensive EU cyberinfrastructure

Welcome to the EOSC Portal Catalogue and Marketplace

Integrated platform that allows easy access to lots of resources for various research domains along with integrated data analytics tools. Browse by scientific domain, resource category or provider and, if you need help, we are here for you!

Find EOSC Resources that suit your use case yourself
- Browse through catalogue
- Describe your use case and get support from our experts
- Go to your projects

Medical & Health Sciences
- Engineering & Technology
- Natural Sciences
- Generic
- Humanities
- Social Sciences
- Other
- Other
- Compute
- Data management
- Networking
- Processing & Analysis
- Security & Operations
- Sharing & Discovery
- Storage
- Training & Support
European Open Science Cloud
A comprehensive EU cyberinfrastructure

Welcome to the EOSC
Communities and infrastructures

- ANDS
- Atlas of Living Australia
- BIOEXCEL
- CCDC
- Copernicus
- Crossref
- CSIC
- DataCite
- DICE
- EC3 Portal
- EGI
- EGI Applications on Demand
- EO Pillar
- EOSC-hub project
- EOSC PaN
- Europeana
- GBIF
- Geohazards Thematic Exploitation Platform (GEP)
- Group on Earth Observation (GEO)
- Infrastructure Manager (IM)
- IS-ENES
- OBIS
- PaaS Orchestrator
- Scopus
- Taylor & Francis
- WeNMR Suite

- Application Lifecycle Enabler 4 Cloud - Alien4Cloud
- ATMOSPHERE
- California Digital Library
- CLARIN
- COVID-19 response
- CSC Enterprise
- D4Science
- DEEP-Hybrid-DataCloud
- Digital Science
- ECOPOTENTIAL Virtual Laboratory
- EGI-ACE
- Elixir
- EOSC DIH
- EOSC-Life
- EUDAT
- European Space Agency (ESA)
- gCube System
- Global Earth Observation system of Systems (GEOSS)
- IFCA
- INSTRUCT-ERIC
- National Infrastructure for Research Data (NIRD)
- Open Geospatial Consortium
- Real Jardín Botánico
- SeaDataCloud
- VAMDC
- XDC

Medical & Health Sciences
Engineering & Technology
Natural Sciences

Generic
Humanities
Agricultural Sciences

Social Sciences
Other
Other

Compute
Data management
Networking

Processing & Analysis
Security & Operations
Sharing & Discovery

Storage
Training & Support

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- CSC Enterprise
- D4Science
- DEEP-Hybrid-DataCloud
- Digital Science
- ECORBOTENTIAL Virtual Laboratory
- EGI-ACE
- EOSC DH
- EOSC-Life
- EUDAT
- European Space Agency (ESA)
- gCube System
- Global Earth Observation system of Systems (GEOSS)
- IFCA
- INSTRUCT-ERIC
- National Infrastructure for Research Data (NIRD)
- Open Geospatial Consortium
- Real Jardín Botánico
- SeaDataCloud
- VAMDC
- XDC
Comments on ROI for Large-Scale Projects

Organizing cyberinfrastructures to measure ROI makes sense!

• Historically, the US has funded large-scale projects and supercomputer centers largely independently of one another, with only modest efforts made to ensure that the resulting cyberinfrastructures can work together. Exceptions include the XSEDE multi-institution project and certain cross-domain, cross-cutting centers such as those focused on cybersecurity.

• European projects have placed a much higher emphasis on producing tools that work across multiple domains and projects to fit together into an overall infrastructure. *Pro:* much more interoperability. *Con:* much more bureaucracy.

• In my view, much more comprehensive efforts to define and quantify the results of scientific research computing and data projects and describe their outputs in qualitative terms that can be compared across modes of delivery are needed in the US effort. Current efforts are fragmented, idiosyncratic, and disconnected.
NSF CAC Project: Data Center Control For Renewable Energy Applications

Presenter:
Alan Sill, Texas Tech University

CAC Project Participants:
Tommy Dang, Texas Tech University
Yong Chen, Texas Tech University
Elham Hojati, Texas Tech University
Ghazanfar Ali, Texas Tech University
Jie Li, Texas Tech University

Project Partners:
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Stephen Bayne, Texas Tech University
Cesar Negri, Texas Tech University
Andrew Grimshaw, Lancium
Vana Venkataswamy, University of Virginia / Lancium

Semi-Annual IAB Meeting
October 28, 2020
Online Event
This project applies previous CAC work in data center automation, analytics, and control standards and methods to this problem.

For most computing centers, energy can add up to approximately the same cost as the computing equipment itself over its usable lifetime.

Availability of large quantities of renewable energy such as wind and solar arrays can break the cost curve for large scale computing.

Wind power and solar energy are increasingly available, but unlike previous sources such as hydroelectric plants, each has highly variable (sometimes even negative!) cost and uneven availability.

Strongly leverages new Redfish data center automation protocol from DMTF.

To make best use of renewable energy sources, data centers need to be sited nearby these sources to reduce transmission infrastructure. As a result, they need to be remotely controllable and highly automated.
GLEAMM Microgrid Test Facility

- SEL RTAC 3530 Controller
- 500kW Backup Diesel Generator
- 30kW Outback Inverters System with 48V / 1600Ah Lead Acid Battery
- MCC Panel and Automatic Transfer Switch
- Test Computing Nodes
- Solar Inverters
- 150kW Solar Plant
- 900kW Wind Turbines
- 1MW Load Banks
- 1MW Load Banks
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30kW Outback Inverters System with 48V / 1600Ah Lead Acid Battery

MCC Panel and Automatic Transfer Switch

Test Computing Nodes

Solar Inverters

150kW Solar Plant

900kW Wind Turbines

1MW Load Banks
Optimum HPC and Energy Usage Scheduling Simulation

Detailed electrical model of Datacenter

- Diesel Generator
- Solar Plant
- Outback Storage Backup

Electric power and energy storage predictions used to schedule HPC workloads, checkpointing / hibernation
References


- Global Laboratory for Energy Asset Management and Manufacturing (GLEAMM): https://gleamm.org

- NSF-funded Cloud and Autonomic Computing Industry/University Cooperative Research Center: https://nsfcac.org
"Any opinions, findings, conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the Networking and Information Technology Research and Development Program."

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