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 <u>return</u> for your organization, region, or project

- Financial aspects
- Non-financial modes of return

Defining <u>investment</u>

- 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
https://www.nytimes.com/2008/09/15/us/politics/15text-biden.html

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.

~~Cost center~~

Research income

Academic output

Productivity

Discovery

Community

Products

Impact

Learning

Patents

Innovation

Awards & recognition

Training

Definition of “Return”

Simplest quantifiable numerical form: Financial aspects

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

- <u>Raw value</u> of externally funded research supported
- F&A / <u>indirect costs</u> obtained through such research
- <u>Charges to users</u> for access to research computing and data infrastructure
- <u>Cost avoidance</u> 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

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

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

Table 2

Output	Outcome	Nonfinancial measures of outcome	Impact
New discoveries reported in publications	Publications	Number of publications, citations of publications, impact factors of publications (and the journals in which publications appear	Improved quality of life for people
Productivity	Shorter time to publications	Time saved	Better management of natural and personnel resources
People trained in areas in which they would otherwise not have been trained	A better-trained STEM workforce	Increased salary, greater employment security for the individual	A better-trained workforce for the economy; Improved global competitiveness for any given country
Awards, press notices	Any award, e.g., Nobel Prize	Numbers, types of awards	Recognition of a particular invention's significance; reputational benefits for the people and organizations winning the award
Patents and licenses	An invention is legally protected by exclusive use of the patent holder or licensee	Number of patents	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

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

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

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.)

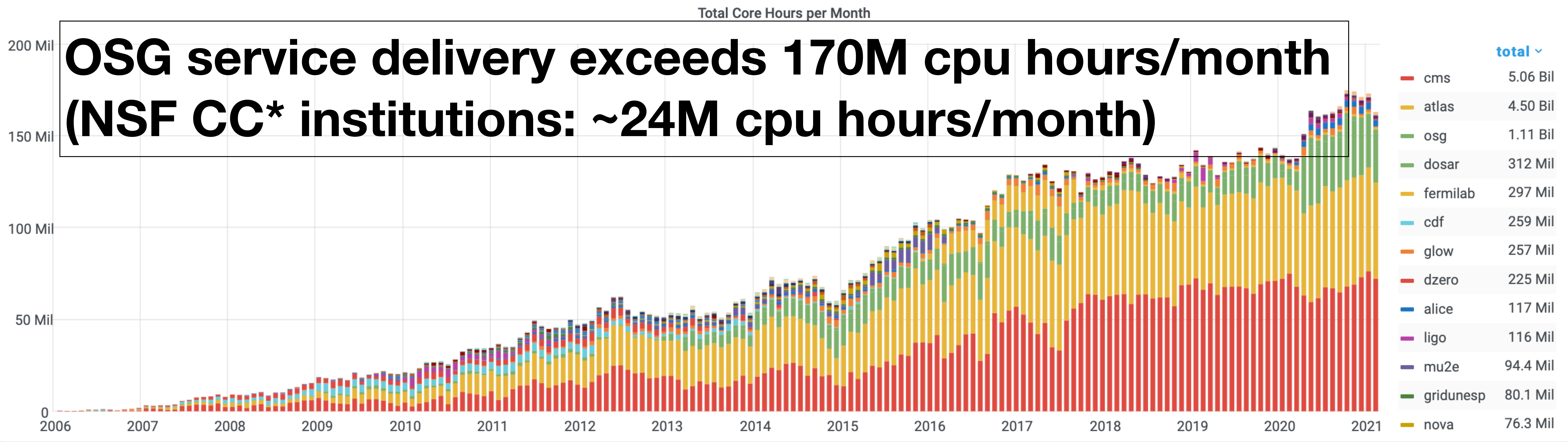
- A wide variety of commercial cloud use cases has already arisen in research computing and data settings in which extra expense of such delivery mechanisms is not the predominant factor, and funding agencies have delivered mechanisms to explore these use cases. Comprehensive efforts to optimize ROI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

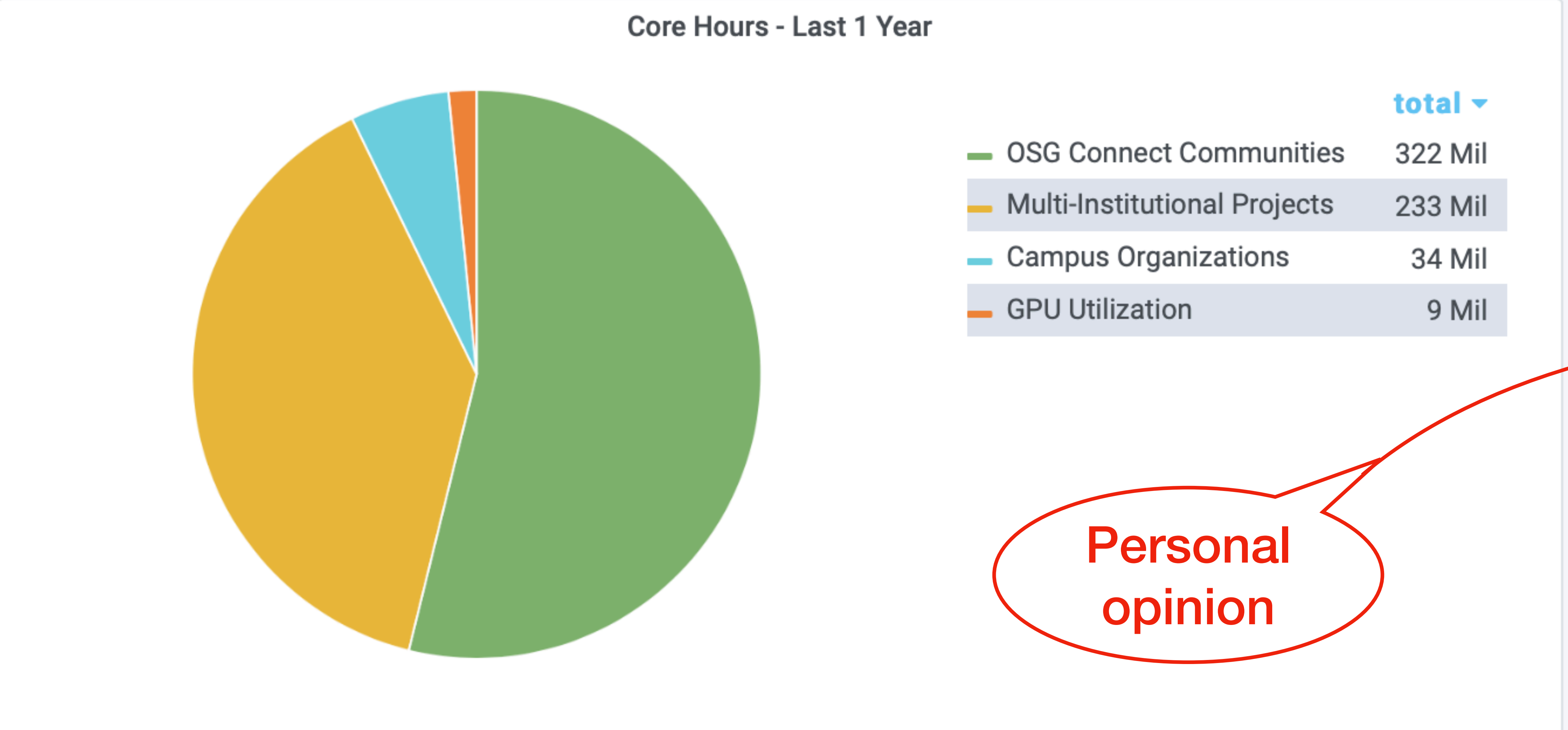
- Europe and the US notably diverge strongly in the organization of funding opportunities to support and make use of coherent science grids and clouds.

- 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)





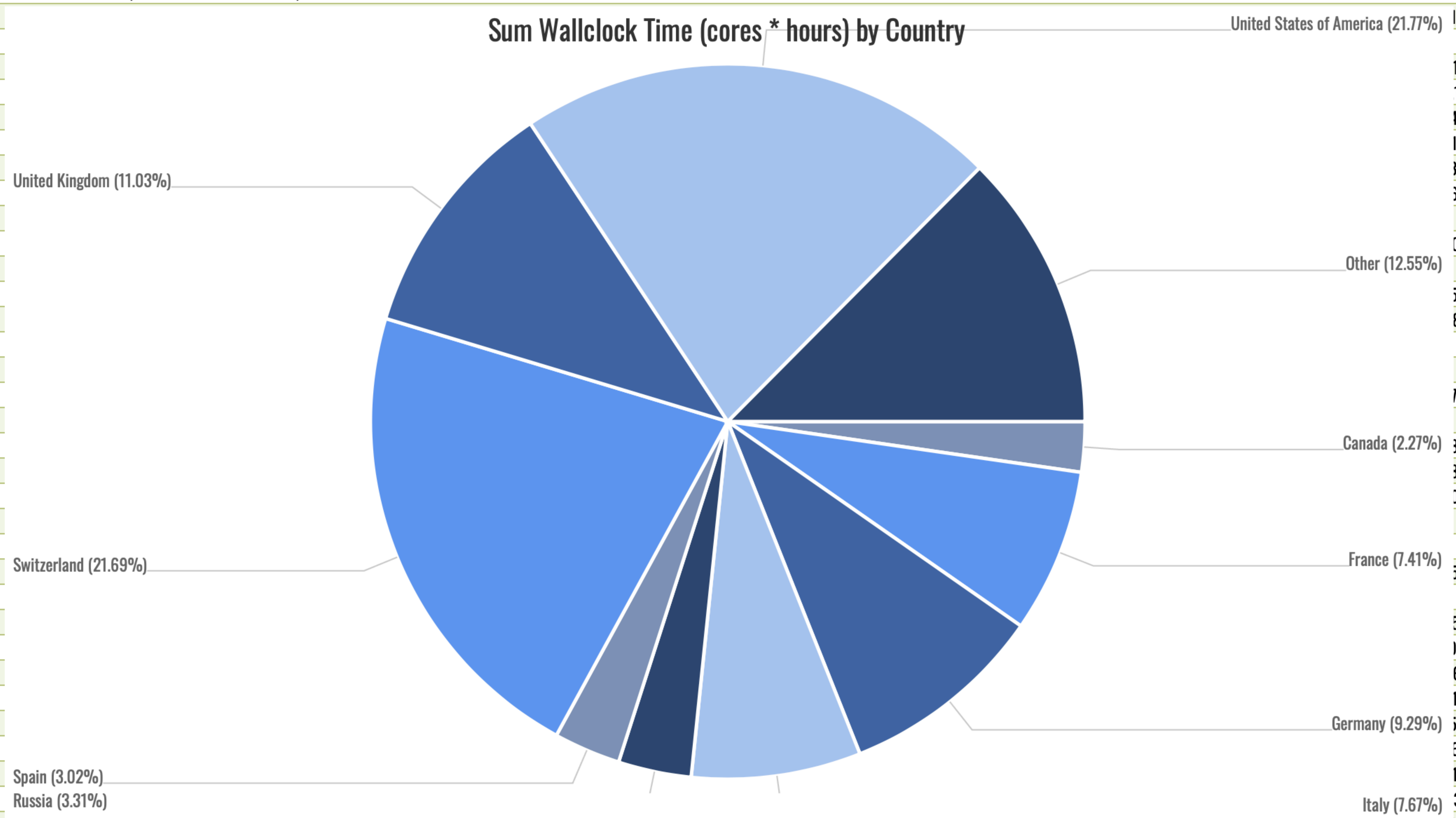
Personal opinion

- 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

C	May 2020	Jun 2020	Jul 2020	Aug 2020	Sep 2020	Oct 2020	Nov 2020	Dec 2020	Jan 2021	Feb 2021	Total
Algeria	125	112	451	536	436	122	854	223	272	233	3,572
Australia	1,354,062	1,214,099	1,228,622	995,987	1,044,157	1,023,283	1,013,484	856,652	91,777	0	11,608,031
Austria	498,450	584,134	350,965	436	0	0	0	0	0	0	2,875,747
Azerbaijan	106,312									102,340	725,585
Belarus	98									7	1,107
Belgium	3,416,011									197,884	49,115,503
Brazil	1,007,820									124,114	13,925,577
Canada	10,522,533									401,085	161,268,412
Chile	188,672									183,259	5,504,045
China	1,177,708									394,502	14,869,543
Czech Republic	5,222,515									521,004	78,797,767
Denmark	19									3,181	102,384
Estonia	2,860,439									031,670	45,265,439
Finland	254,488									91,315	4,025,022
France	43,658,099									502,091	526,548,519
Germany	51,833,510									829,175	659,510,193
Greece	38,272									45	566,326
Hungary	524,532									0	1,848,764
India	2,610,963									748,584	28,425,832
Iran	267									0	1,671
Israel	3,160,364									361,924	30,122,016
Italy	48,732,933									346,159	544,516,373
Japan	5,750,760									037,293	68,142,266
Mexico	54,656									0	1,457,567
Morocco	0									104	105
Netherlands	9,593,083									548,201	111,047,756
Pakistan	38,437									0	276,659
Poland	4,307,109									513,442	54,547,502
Portugal	1,073,513									048,396	10,824,315
Romania	3,957,459									647,142	59,021,154
Russia	19,221,774									102,270	234,926,351
Slovakia	1,524,993									540,844	17,756,687
Slovenia	7,565,961									615,955	79,197,809
South Africa	1,339,981									114,698	11,958,558
South Korea	2,810,057									370,778	40,100,552
Spain	17,269,407	16,332,789	19,427,876	16,863,855	17,205,326	18,933,069	22,350,297	19,116,862	18,018,108	14,830,999	214,556,409
Sweden	9,430,895	9,039,026	8,890,253	7,932,535	6,992,347	9,866,373	12,437,275	9,105,540	6,250,827	4,692,055	104,821,148
Switzerland	127,435,824	122,647,309	127,919,327	130,479,171	118,968,041	126,479,010	122,564,411	139,035,626	145,778,937	128,056,208	1,540,442,307
Taiwan	2,916,300	3,048,758	3,051,166	3,083,870	2,704,409	3,252,344	3,224,994	2,733,637	3,088,135	2,761,235	36,196,444
Turkey	464,618	309,035	402,856	283,814	246,119	209,075	83,740	246,995	268,900	191,607	3,451,902
Ukraine	433,042	406,252	402,190	342,195	354,651	365,685	392,439	441,915	411,608	339,803	4,742,507
United Kingdom	68,481,630	63,916,226	69,059,760	72,821,958	72,908,412	72,307,570	71,857,955	67,619,719	63,056,087	32,418,776	783,430,449
United States of America	121,365,868	118,166,820	134,416,591	126,083,185	126,958,205	133,934,188	133,156,952	137,975,992	140,503,870	130,259,587	1,546,192,072



- 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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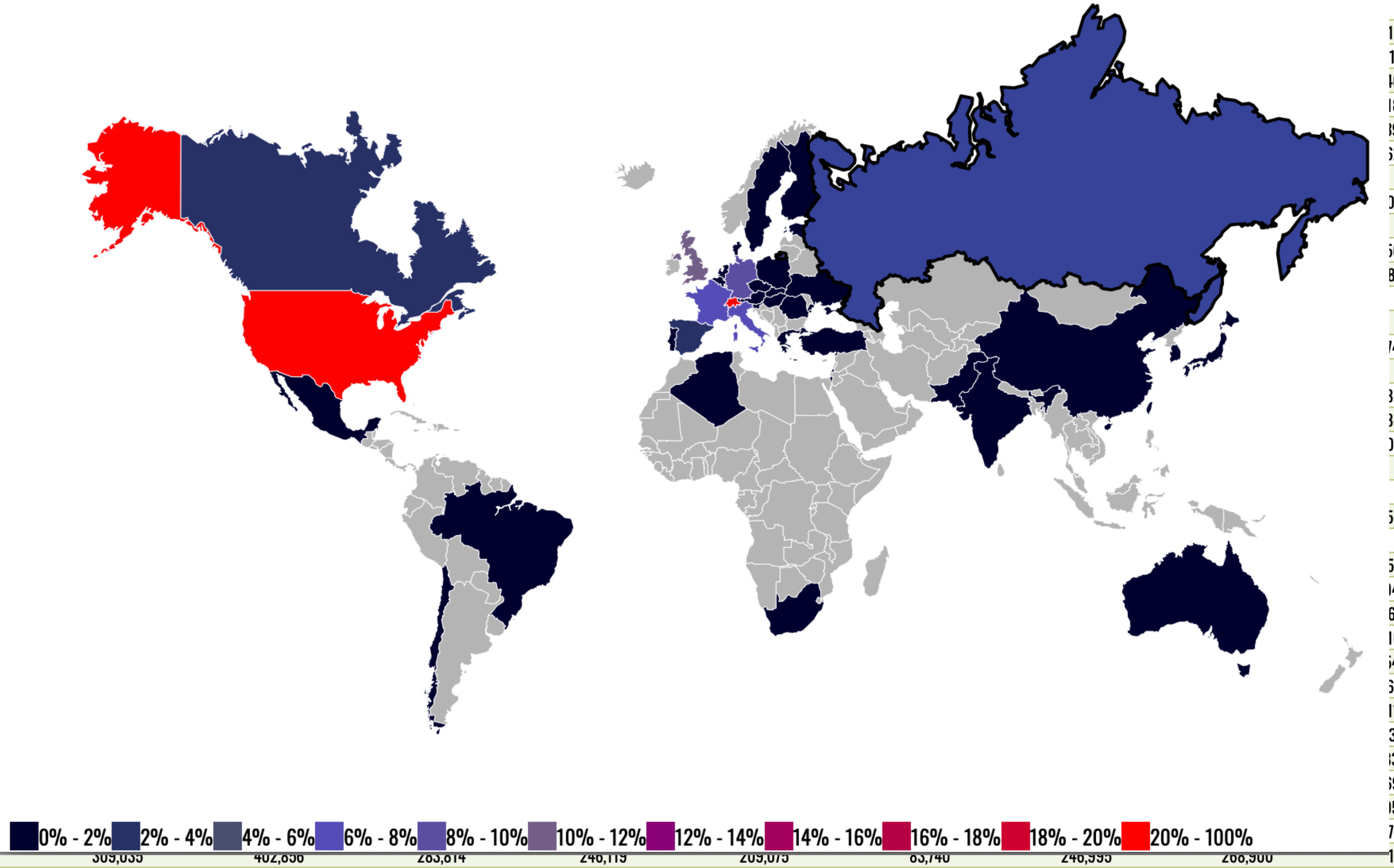

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European Open Science Cloud

A comprehensive EU cyberinfrastucture

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	Agricultural Sciences
Social Sciences	Other	Other

Compute	Data management	Networking
Processing & Analysis	Security & Operations	Sharing & Discovery
Storage	Training & Support	

European Open Science Cloud

A comprehensive EU cyberinfrastucture

Welcome to the EOSC

EUROPEAN OPEN SCIENCE CLOUD

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

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ELIXIR
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EOSC-Life
EUDAT
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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 <u>define</u> and <u>quantify</u> the results of scientific research computing and data projects and describe their outputs in qualitative terms that can be <u>compared across modes of delivery</u> are needed in the US effort. Current efforts are fragmented, idiosyncratic, and disconnected.

NSF CAC Project: Data Center Control For Renewable Energy Applications

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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:

Sandeep Nimmagadda, Texas Tech University
Stephen Bayne, Texas Tech University
Cesar Negri, Texas Tech University
Andrew Grimshaw, Lancium
Vana Venkataswamy, University of Virginia / Lancium

Cloud and Autonomic Computing Center

A U.S. National Science Foundation Industry/University Cooperative Research Center

Semi-Annual IAB Meeting

October 28, 2020

Online Event

TEXAS TECH UNIVERSITY

THE UNIVERSITY OF ARIZONA

UNT EST. 1890

TEXAS STATE UNIVERSITY

Universidad de Sonora

AUM AMERICAN UNIVERSITY OF MALTA

Project Overview

- 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 <u>nearby these sources</u> to reduce transmission infrastructure. As a result, they need to be r<u>emotely controllable and highly automated</u>.

GLEAMM Microgrid Test Facility

SEL RTAC 3530 Controller

500kW Backup Diesel Generator

30kW Outback Inverters System with
48V / 1600Ah Lead Acid Battery

Test Computing Nodes

MCC Panel and Automatic Transfer Switch

150kW Solar Plant

Solar Inverters

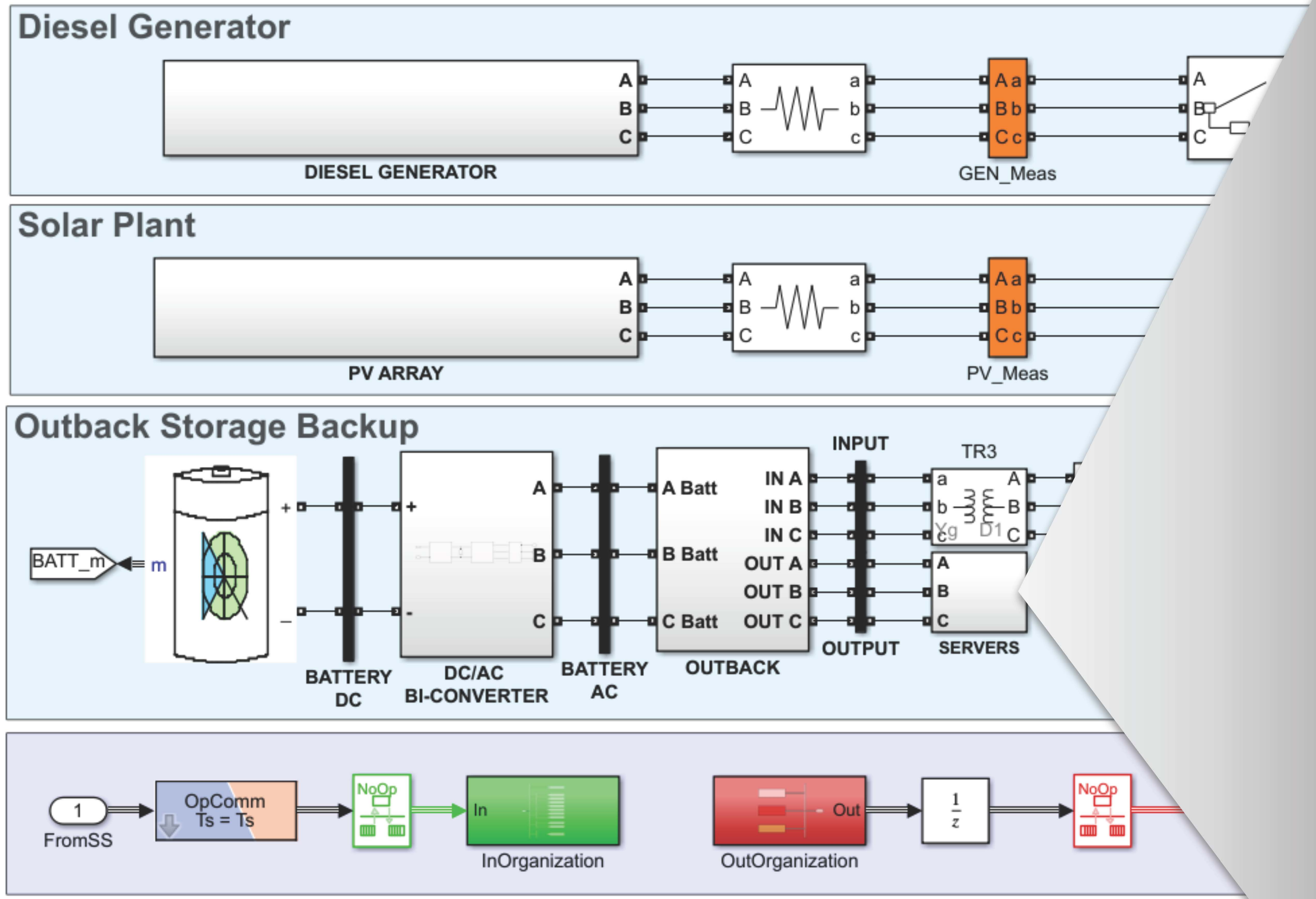
900kW Wind Turbines

1MW Load Banks

NSF CAC Cloud and Autonomic Computing Center | TEXAS TECH UNIVERSITY | THE UNIVERSITY OF ARIZONA | TEXAS STATE UNIVERSITY | UNT EST. 1890 | VCU VIRGINIA COMMONWEALTH UNIVERSITY | AUM AMERICAN UNIVERSITY OF MALTA | Universidad de Sonora

Optimum HPC and Energy Usage Scheduling Simulation

Detailed electrical model of Datacenter



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

CAC Cloud and Autonomic Computing Center · TEXAS TECH UNIVERSITY · THE UNIVERSITY OF ARIZONA · TEXAS STATE UNIVERSITY · UNT EST. 1890 · AUM AMERICAN UNIVERSITY OF MALTA · Universidad de Sonora

References

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- European Open Science Cloud: https://eosc.eu and https://eosc-portal.eu

- 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

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