The webinar will start momentarily....

U.S. DEPARTMENT OF ENERGY

Barriers to Data Center Efficiency: Insights from Experts and Operators

December 11, 2023

FEMP
Federal Energy Management Program

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BERKELEY LAB
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CENTER OF EXPERTISE
FOR ENERGY EFFICIENCY IN DATA CENTERS

Webinar Agenda

- Introduction
- Overview of Previous Research (Phase I)
- Phase II Methods
- Phase II Findings
  - Environmental impact of DC site selection
  - Brain drain impedes efficiency in federal centers
  - Performance metrics vary by facility characteristics
  - Key role of vendors in procurement
- Discussion
- Resources and Q&A

Findings Overview

- Environmental impact of DC site selection
- Brain drain impedes efficiency in federal centers
- Performance metrics vary by facility characteristics
- Key role of vendors in procurement

Introduction

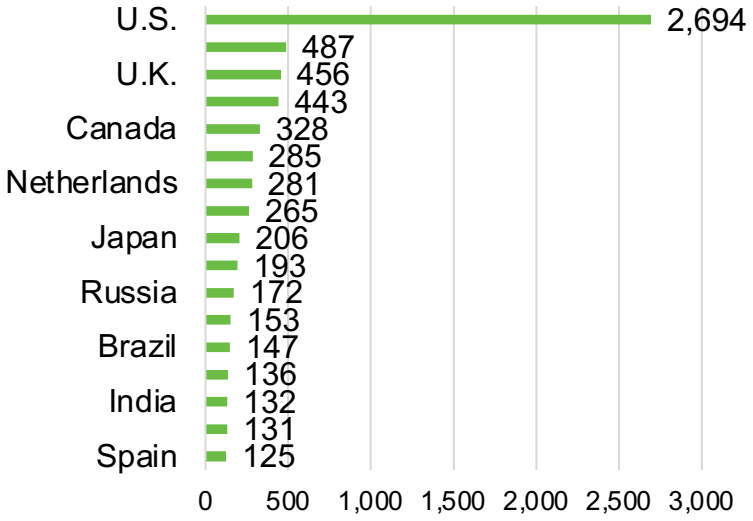
Learning Objectives

- Educate data center stakeholders on the **impact of data center site selection**
- Educate data center stakeholders on the negative impacts of talent attrition, and develop skills for **succession planning**
- Educate stakeholders on a data center performance **metrics**, with examples of evolving industry relationships to **network resiliency** and energy use
- Educate stakeholders on the influence of **vendors** on procurement practices and their potential as partners in decarbonization and efficiency
- Use these concepts to develop for stakeholders a **continuous improvement** process

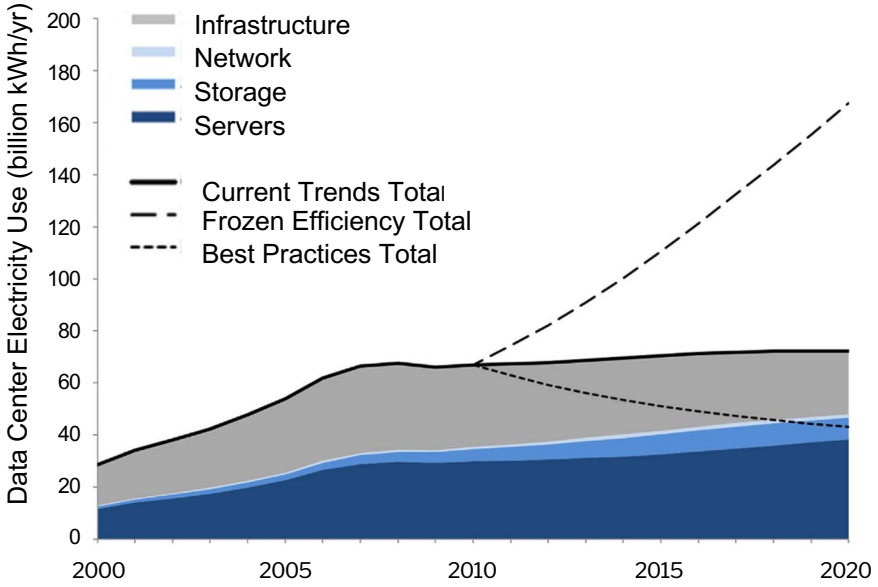
Background: The U.S. dominates the data center industry & is poised to grow at a CAGR of 20%

- Data centers currently consume between 2-5% of U.S. electricity (this represents between 0.3-0.7 quads of electricity; 0.9-2.1 quads of primary energy)
- Electricity costs were $13B for US businesses in 2014 – doubles every 5 years

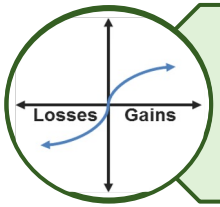
Number of data centers worldwide by country, 2021



U.S. Data Center Equipment Trends

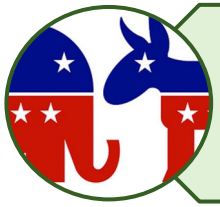


People make decisions informed by more than money and engineering solutions



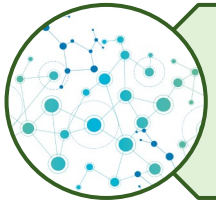
Behavioral Economics

Economic Sociology



Social Psychology

Situational Factors



Social Networks

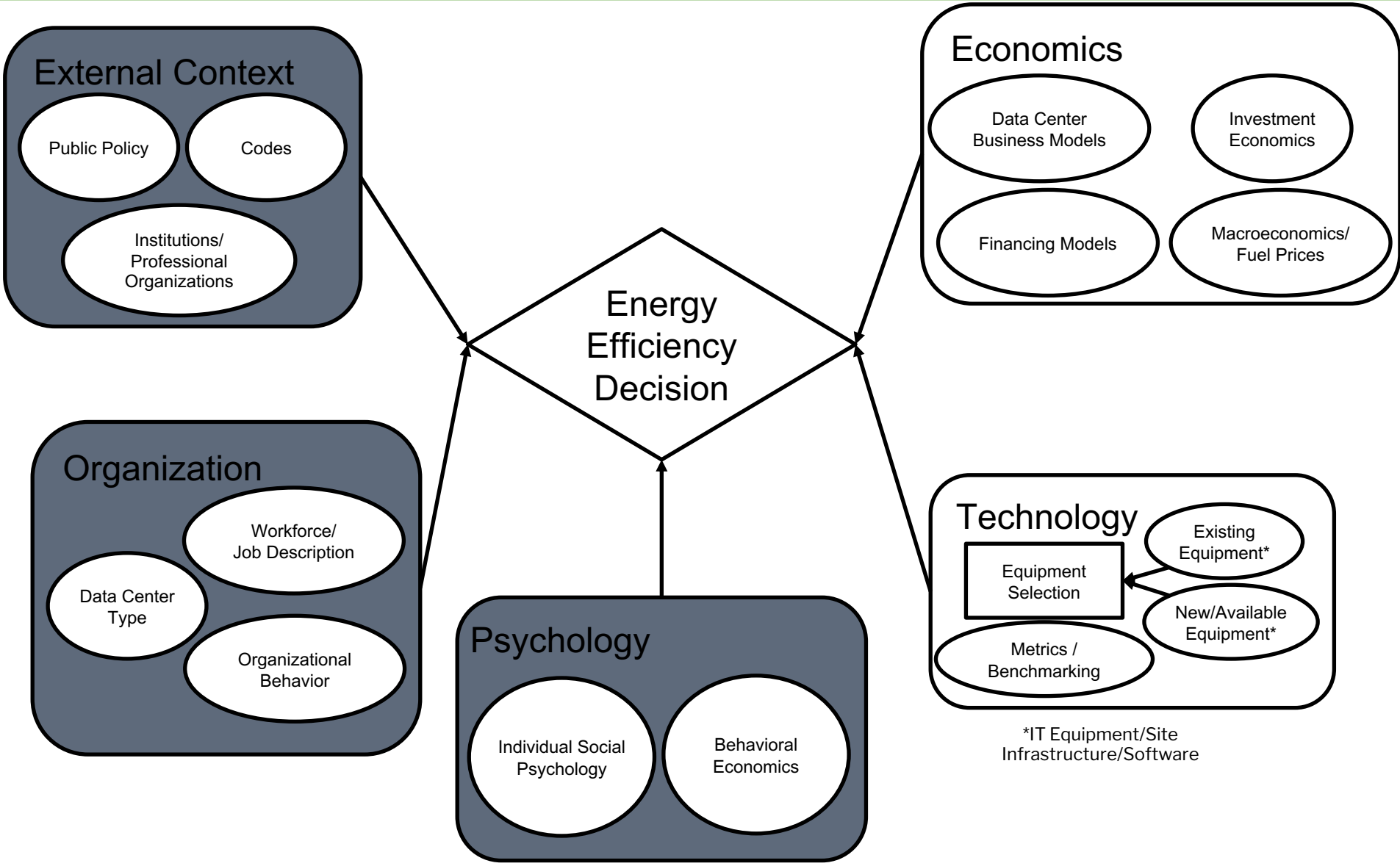
Approach

- The Center of Expertise for Energy Efficiency in Data Centers (CoE) has completed a two-phase program of research for identifying key organizational barriers and implementation measures to increase data center energy efficiency

- Phase I: Literature Review (previous work)

- Phase II: Interview Study (presented today)

Phase I Methods: Literature review of 86 sources relating to barriers to energy efficiency in *data centers (DCs)*

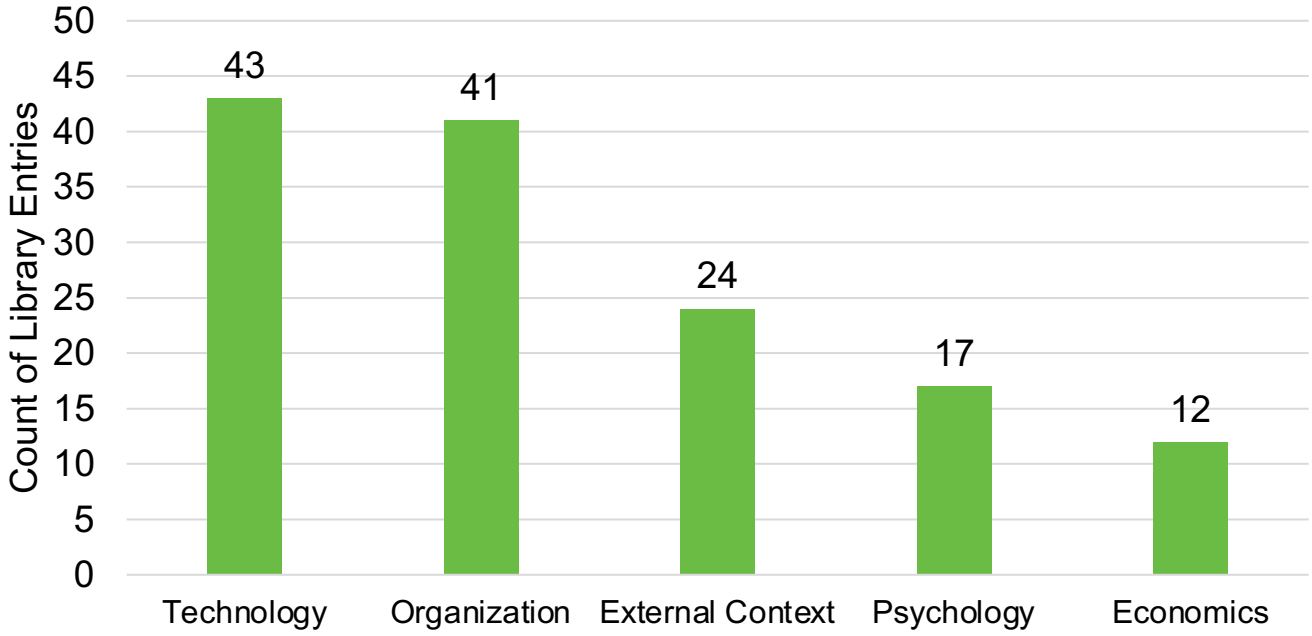


Phase I Findings: Organizational barriers were the second most discussed barrier category in the literature

This bar chart represents the count of library entries receiving each tag.

Note that entries could be assigned multiple tags so the sum of these tag totals is not equal to the total number of library entries.

Technology and Organization are the most frequently addressed topics within the library.



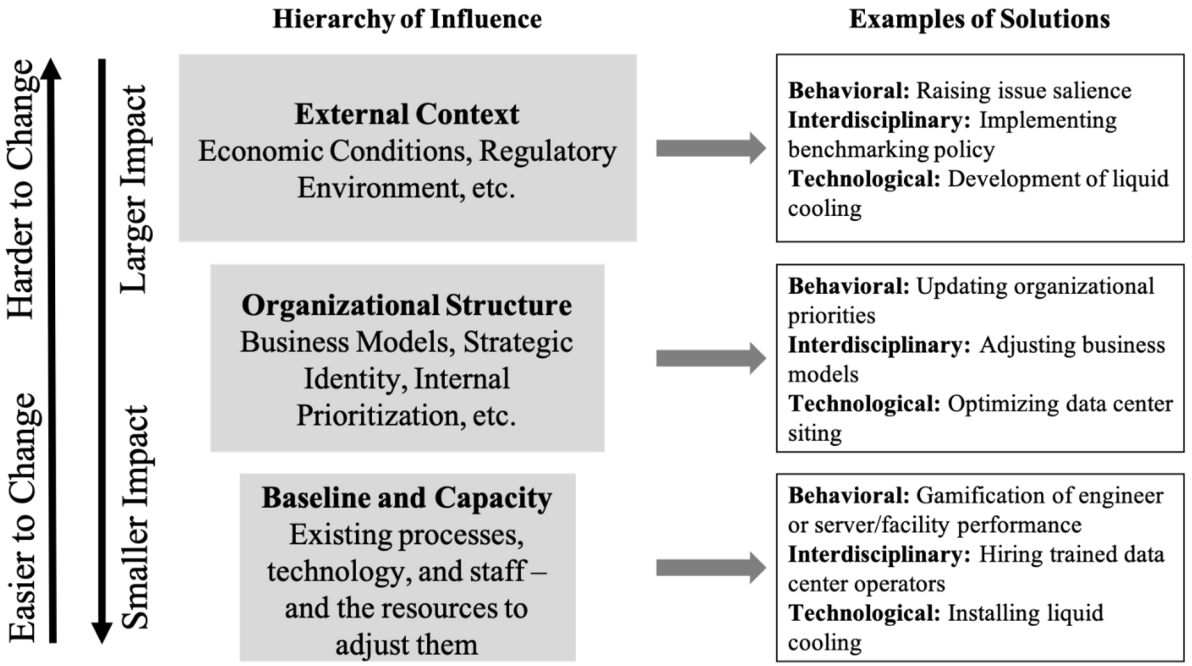
Hanus, N., Newkirk, A., & Stratton, H. (2023). Organizational and psychological measures for data center energy efficiency: barriers and mitigation strategies. *Energy Efficiency*, *16*(1), 1-18.

Phase I Findings: Barriers from the literature fell into three categories of varying influence and inertia to change

This figure illustrates the taxonomy of barriers we found in the literature.

We hypothesized a hierarchy of influence from barriers in the external context, organizational structure, and baseline and capacity of the data center.

Phase I research was published in *Energy Efficiency* in January.



Hanus, N., Newkirk, A., & Stratton, H. (2023). Organizational and psychological measures for data center energy efficiency: barriers and mitigation strategies. *Energy Efficiency*, *16*(1), 1-18.

Phase II Methods

Interview Process

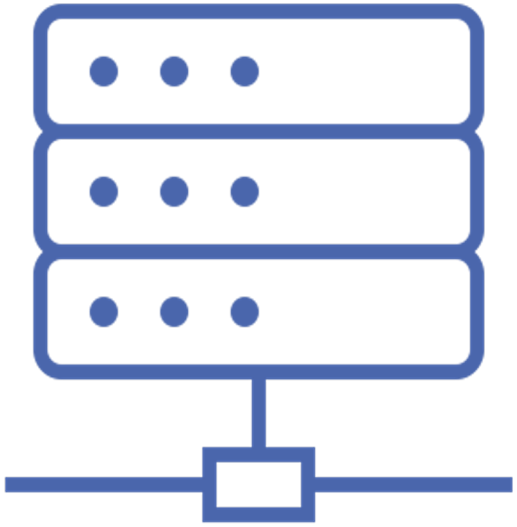
Hour-long, virtual interview

Three thematic sections:

1. *Procurement and Operations*
2. *Metrics and Monitoring*
3. *Barriers to Energy Efficiency*

Barriers section includes inventory of barriers based on our literature review (c. *Hierarchy Figure)*

Our Sample



- **16 total:** 7 DC experts and 9 owners/operators
- Experts and owners/operators received **similar but non-identical** interview protocols
- Covered a variety of perspectives:
  - Government, private, and non-profit (e.g., university, nonprofit hospital)
  - Colocation, enterprise, HPC, and hyperscale/cloud
  - Other energy intensive buildings (e.g., hospitals, labs)
  - Geographical diversity
- Ranged in size :
  - 3,000 - 250,000 sq. ft.
  - 50 – 2,000 server racks
- All DCs employed at least some off-the-shelf IT hardware

List of Barriers Identified in Interviews

Barrier Class	New Barrier	Experts	Operators
Baseline	Water Efficiency Tradeoff	✓	✓
	HPC Prestige	✓	
	Global Services	✓	
	Utility Interaction	✓	
Organizational	Lack of Staff Availability	✓	✓
	IP Propriety	✓	
	Brain Drain	✓	✓
	Legal Risk Aversion		✓
External Context	Land Use Regulations and Zoning	✓	✓
	Lack of Industry Performance Benchmarks	✓	✓
	Domain Silos	✓	✓
	Public Procurement Regulations		✓

Findings Overview

Environmental impact of DC site selection

Brain drain impedes efficiency in federal centers

Performance metrics vary by facility characteristics

Key role of vendors in procurement

Environmental Impact of DC Site Selection

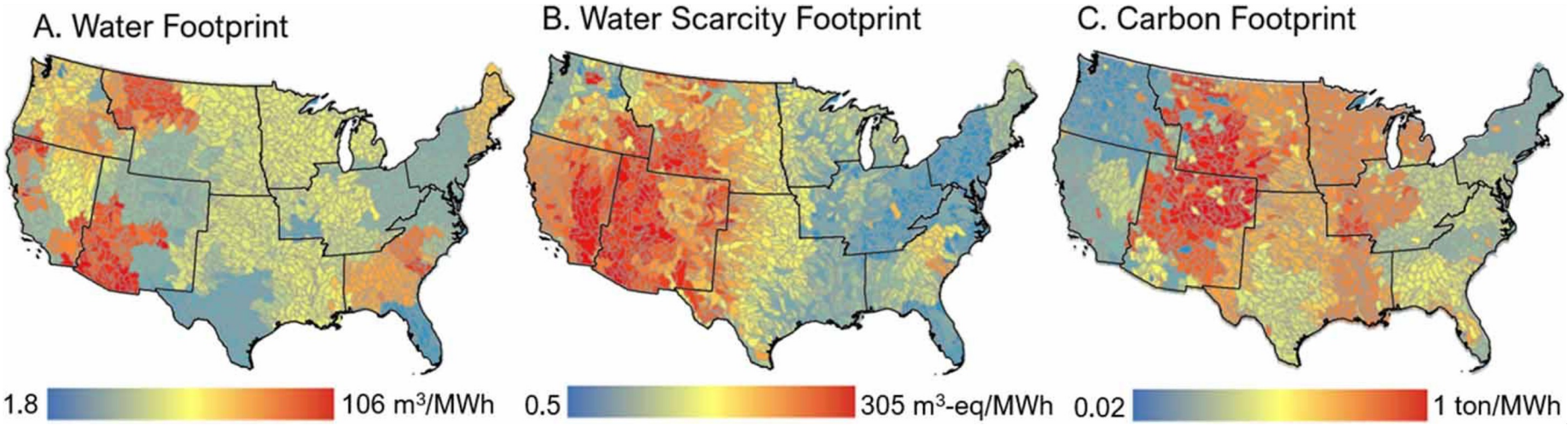
Site Selection: Most Significant DC Choice

- The greatest determinant of DC *energy use* is site (Jones, 2018; Turek & Radgen, 2021)

- The greatest determinant of DC *water use* is site (Chen and Wemhoff 2022; Siddik, Shehabi, and Marston 2021; Karimi et al. 2022)

- DC *carbon emissions* are associated with:
  - Hardware embodied emissions (majority of emissions highly efficient centers) (Singh and Ogunseitan 2022; Monserrate 2022; Gupta et al. 2020)
  - Electricity generation (scope 2) emissions for:
    - IT Load
    - Cooling and Other Loads
  - Embodied emissions are site independent, opex emissions depend on quantity and carbon intensity of electricity

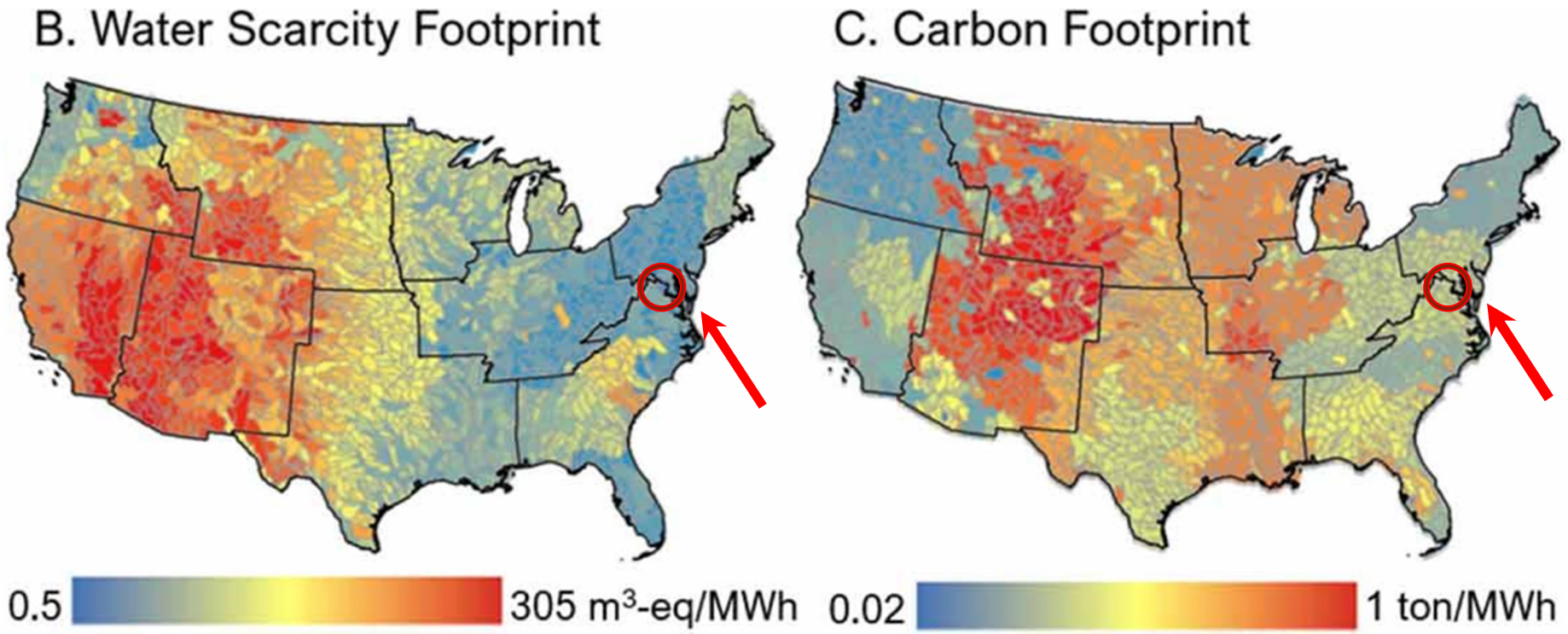
Environmental Footprint of U.S. DC



Siddik, Md Abu Bakar, Arman Shehabi, and Landon Marston. 2021. "The Environmental Footprint of Data Centers in the United States." *Environmental Research Letters* 16 (6): 064017. https://doi.org/10.1088/1748-9326/abfba1.

Figure illustrates the environmental footprint of a hypothetical 1 MW data center across the continental United States.

Impact of Northern Virginia's DC Cluster



It was estimated that 70% of the world's web traffic in 2019 occurred in northern Virginia's "data center alley" (Monserrate 2022):

- What are the *water* implications of that cluster?
- What are the *carbon* implications of that cluster?
- What might the *advantages and disadvantages* of that concentration be?

Factors that Influence Site Selection

- "I think the majority of data centers are actually being put in the wrong place: We see data centers trying to basically crowd into the middle of metros which makes no sense at all… realistically **data centers should be on the periphery of cities and tied directly to the high power grids**… Pre-existing facilities especially have no incentive to leave the market [and their current] location."

  – Enterprise Operator

- "[A barrier to efficiency is] if you are required to have proximity to a certain region for XYZ reason, and the **climate or the conditions on that region leads to a lower efficiency** for the center…[Let's say for instance] you're contracted to be the flagship HPC facility of Spain, you're not actually allowed to site it outside of Spain. You have multiple **countries that will not allow you to relocate** [even distributed services] outside of the country."

  – Hyperscale Operator

Brain Drain Impedes Efficiency in Federal Centers

Federal Data Center Challenge: Brain Drain

"It's brain drain, the folks that are leaving, the **succession planning has to be in place** … across all areas of the data center we have a lot of people leaving. I'm actually in that category of being old. So I actually am trying, with three or four people right now, to do succession planning for me"

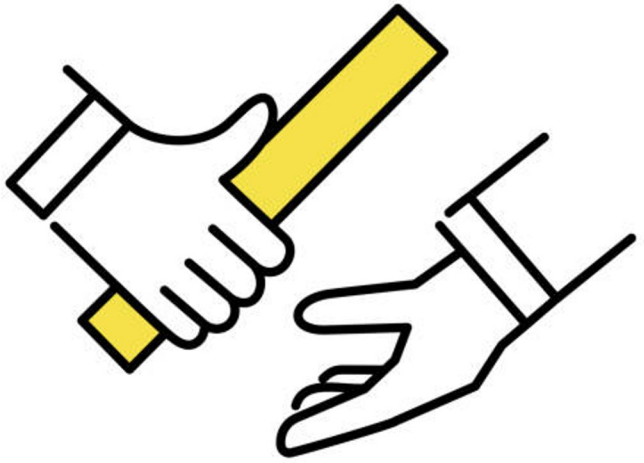
– Government DC Operator

Scope of Brain Drain Challenge

- Federal IT workforce approaching a generational transition, making transfer of human capital vital to maintaining reliability and efficiency (Wesemann 2022)
- Succession planning efforts known to correlate with higher organizational performance (Goldring 2015)
- Failure to address talent attrition can lead to crucial loss of capabilities and act as a long term drag on performance

Best Practices for Addressing Brain Drain

- Staff should:
  - Review future retirements (Dresang 2017)
  - Implement a formal succession planning strategy (Wilkerson 2007)
  - Assign an energy efficiency champion (Loomis 2017)
- Outsourcing of DC services to cloud providers where appropriate an alternative way to address attrition related brain drain



Performance Metrics Vary by Facility Characteristics

Performance Metrics Background

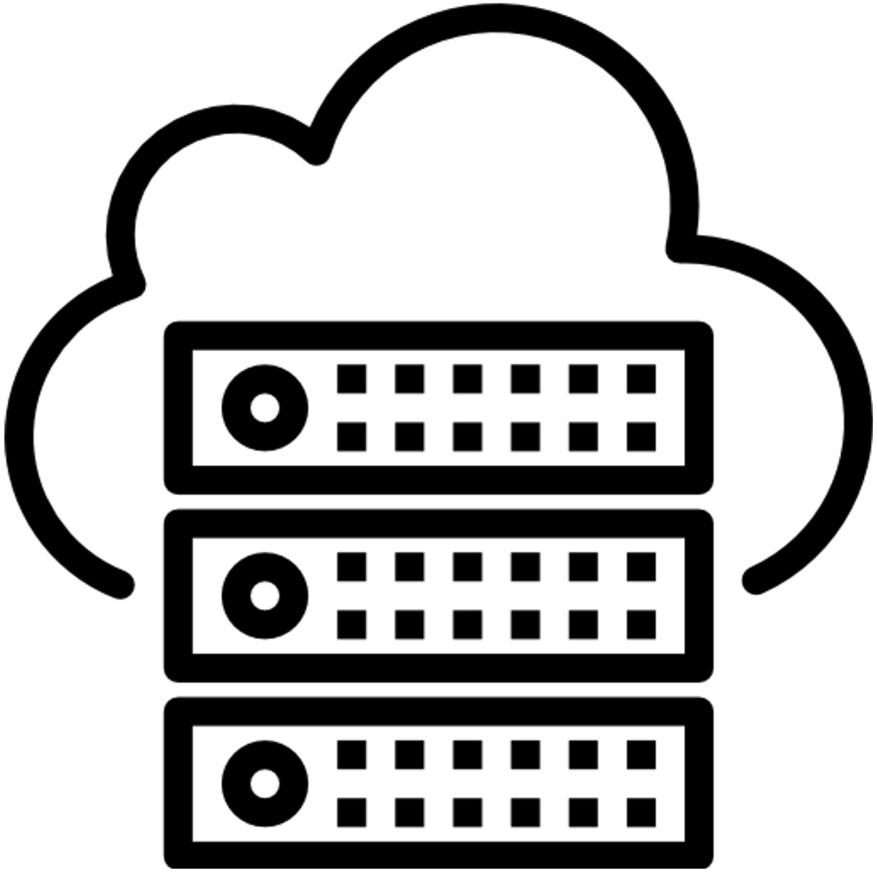
- Plentiful research literature about the limitations and misapplication of PUE (Yuventi and Mehdizadeh 2013)
- Expectation that increased performance would be associated with more comprehensive or better aligned metrics (Klemick et al. 2019, Horner and Azevedo 2016)
- Proposed metrics incorporate siting factors (Li et al. 2020) and researchers predict industry energy performance improvements once they coalesce around one (Guitart 2017)

No Consensus on Advanced Efficiency Metrics in Interviews

- Experts talked about per-use or per-unit metrics, but operators didn't use them.
- Operators had their own metrics, but they were different for each facility.
- The only metric that was used by multiple centers was Water Use Efficiency (WUE).

Respondent Class	Uniquely Provided Metrics
Experts (7)	Managed Services, Infrastructure Capability, Total Cost, Performance (time-to-model solution)
Owners/Operators (9)	Queue Length, Delta T, Energy Reuse Efficiency, Office Energy Usage, Storage Utilization, Sewer Usage, Capability Metric, Water Usage Efficiency (WUE)

Distributed Providers Shifting Towards Network Resilience



- Distributed computing means service need not rely on any particular facility – lower required individual facility redundancy as well (network effect)
- Also enables greater siting flexibility, a way to address siting related barriers to efficiency

> "All the cloud providers, the Googles, the Amazons, they have their redundancy in the network rather than in the data center. They build data centers sometimes without even diesel backup…They're using their network for reliability."
>
> – DC Energy Expert

> "We have an evolving relationship with uptime and reliability. Specifically, moving away from a facility level view to a network level view"
>
> – Hyperscale Enterprise Operator

Different Service Types; Different Needs

- "It might vary for a hyperscale…because if they just lose one edge facility they they're still giving getting out to their clients…Netflix has their primary data center, but they do a lot of edge computing because they want to reduce latency so that little round thing that spins around as you're watching your movies doesn't come up … if they lost an edge [DC], they could still get out their product as opposed to somebody like M&T Bank, if they go down they're in trouble."

  – DC Efficiency Expert

- "I don't think that cost of cloud is really the right metric anymore…7 million in the cloud is very different than 7 million on premise and that 7 million in the next month could turn into 3 or it could turn into 14 depending on what happens with your product and your features…I think your closest proxy would probably be like number of services per cloud provider."

  – Cloud Service Expert

- "Optimizing science and engineering…if you run the computers hotter, you can get to solution faster…you use fewer hours to come to the solution but the cost per hour for cooling may be going up."

  – Scientific HPC Operator

Key Role of Vendors in Procurement

Vendors are Drivers of Procurement

"We will **set a strategy along a product line stick with it**, the manufacturer may grow and change their products but we'll stick with those compatible elements inside of a product line. We do that with HVAC, we do it with UPS, we do it with server infrastructure, we do it with storage we even do it with racks and power distribution units"

– Enterprise Data Center Operator

"We only work with the most common manufacturers, the biggest manufacturers…We're **not really inclined to try some newfangled technology** that saves us 2% on power at the cost of massive outages… [we have] only half a dozen vendors on any piece of equipment and usually fewer. We really don't go outside of those"

– Colocation Operator

Vendor Relationships are Personal

"The last time we went through the [specification] exercise to determine small scale UPS technology or racks, I think in each instance we went to Graybar first and some **trusted partner** there will kind of help guide us through the industry state of things"

– Enterprise Operator

"We had two operators say that it basically just came down to whoever sales person they liked the most was who they bought from. D**ata centers are all relationship based** … Now they're not going to go out of the way and buy a piece of [junk] product, all things equal they're going to the salesperson personality [they prefer] and relationship is a big factor."

– DC Management Software Provider

Vendor Choice is Durable

"We do the same thing here for many years, our standard server infrastructure was Hewlett Packard, at some point that relationship soured, and it switched to Cisco. It switches every 10 or 12 years"

– Enterprise Data Center Operator

"You don't want to screw up somebody's data center because it's so critical and a backbone for so many industries … reliability is so important … even if a machine isn't as optimal if you can trust the salesperson, you like them more you'll buy from that salesperson, even if it's more expensive, even if it's not as good."

– DC Management Software Provider

Discusison

Learning Objectives

Learning Objective	Summary	Suggestions for Practice
Impact of **data center site selection** on facility environmental performance	• DC siting is heavily constrained and major determinant of energy use, water use, and carbon emissions • Experts had lower awareness of siting related issues than operators	Evaluate the impact of Data Center site on environmental performance. Shift DC services to those operators with the greatest siting flexibility where appropriate.
Impact of **brain drain** on federal data center energy efficiency	• Brain drain an impediment to efficiency in the federal sector • Generational transition in IT workforce maces talent attrition a near term concern for federal operators	Engage DC operators in **succession planning**. Review retirements, implement a formal succession planning process, and designate an energy efficiency champion
Diverse **metrics** for performance and evolving relationship to **resilience** & **energy**	• No industry consensus around advanced energy metrics • Distributed IT enables network resilience facility redundancy	Characterize the specific goals and features of your facility to develop their own performance metric; develop skills for continuous measurement and improvement
Influence of **vendors** on procurement and their potential as partners facility improvement	• Vendors are major drivers of procurement • Vendor relationships are personal • Vendor choice is durable	ESCOs can partner with federal facilities to improve facility efficiency through energy savings performance contracting and power purchase agreements

Learning Objectives

- Impact of **data center site selection** on facility environmental performance
- Impact of **brain drain** on federal data center energy efficiency
- Facilities possess diverse **metrics** for performance and evolving relationship to **resilience** & **energy**
- Develop skills for **continuous improvement**
- Influence of **vendors** on procurement and their potential as partners facility improvement

Site Selection Impact

Findings Summary

- DC siting major determinant of energy use, water use, and carbon emissions
- DC site selection is constrained by predominant industry practices, legacy facilities, customer proximity, and other non-performance factors
- Experts had lower awareness of siting related issues than operators

Suggestions for Practice

- Evaluate the impact of Data Center site on environmental performance
- Evaluate potential service resilience impacts of DC site
- Shift DC services to those operators with the greatest siting flexibility where appropriate

Brain Drain Impact

Findings Summary

- Brain drain an impediment to efficiency in the federal sector
- Generational transition in IT workforce maces talent attrition a near term concern for federal operators

Suggestions for Practice

- DC operators should engage in proactive succession planning:
  - Review upcoming retirement
  - Implement a formal succession planning strategy
  - Designate an energy efficiency champion

Diverse Metrics for DC Performance

Findings Summary

- No industry consensus around advanced energy metrics
  - Advanced metrics exist, but they vary significantly by DC type and end use
  - There is no one-size-fits-all
- Distributed IT enables network resilience with lower facility redundancy

Suggestions for Practice

- Characterize the specific goals and features of your facility to build your own performance metric
- Develop skills for continuous measurement and improvement

Continuous Improvement Process Example: Custom Data Center Performance Metric

1. Profile your data center, identify core mission or service
2. Determine existing monitoring capabilities, track indicator related to core mission
3. Evaluate current performance and identify areas for improvement

   [Detailed tools can be found the *CoE Data Center Energy Efficiency Toolkit*]
4. Implement a change in facility design or operation
5. Evaluate effectiveness of intervention through continuous monitoring

Vendors Influence Procurement Behavior

Findings Summary

- Vendors are major drivers of procurement
- Vendor relationships are personal
  - Buyers trust individual vendors to inform them and guide purchases
- Vendor choice is durable
  - These relationships persist for long time horizons except if there is a major problem

Suggestions for Practice

- Energy service companies (ESCO) can partner with federal data centers to improve facility efficiency:
  - Domain knowledge and facility expertise
  - Energy savings performance contracting (ESPC)
  - Power purchase agreement style Energy Sale Agreements (ESAs)

Vendors can be partners in meeting federal emissions reduction targets

E.O. 14057 requires:

- 65% reduction in federal operations carbon emissions by 2030
- 50% reduction in buildings related emissions by 2045
- 100% carbon free electricity by 2030

Data Center Challenges:

- Uptime requirement is a barrier to purchase of 100% renewable power
- Short IT hardware lifecycle drives up embodied emissions
- Energy service companies (ESCOs) can be a valuable partner to improve facility efficiency

Resources and Q&A

Center of Expertise Website

Use CoE's Energy Efficiency Toolkit.

Choose from upcoming live webinars, pre-recorded trainings, and in-person Data Center Energy Practitioner (DCEP) trainings.

Explore the various focus areas of the CoE.

Filter CoE's many resources by type and topic.

Search resources by topics of interest.

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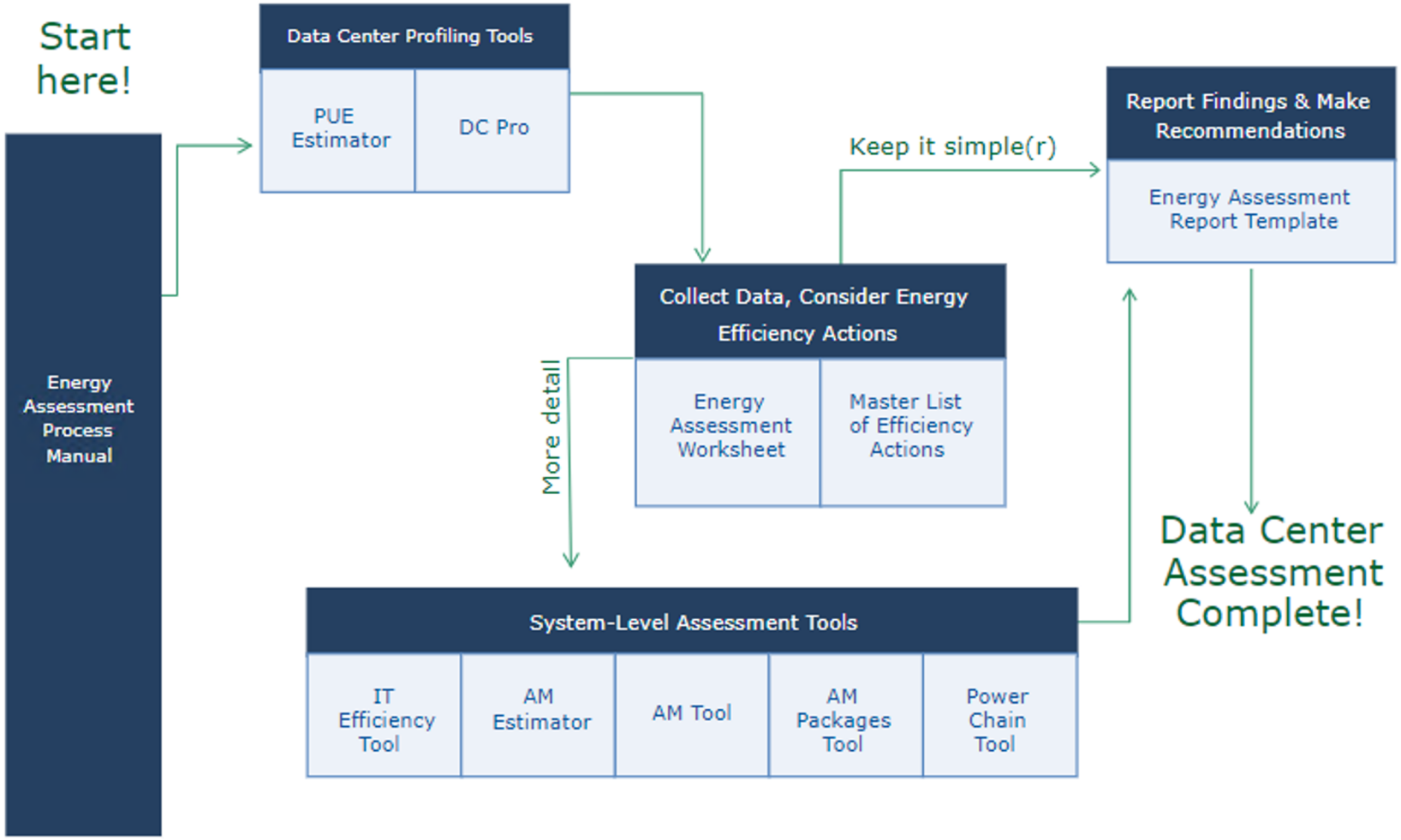
CoE Data Center Energy Efficiency Toolkit



Business Case for EE in Data Centers

- Interactive web resource enables users to identify stakeholders across an organization who are critical to a project's success and assess relevant drivers and barriers.
- Explore resources that can help overcome barriers and win over stakeholders – including successful case studies, CoE tools, training opportunities, etc.

Access the Business Case

ESPC and ESA related resources:

ESPC Webinars

- Potential to collaborate with energy service companies to improve facility performance with reduced upfront costs through Energy Savings Performance Contracts (ESPCs)
- Better Buildings has compiled the ESPC Toolkit
- Available resources cover all steps of the process, including toolkits, case studies, and webinars

ESA Specific Webinars

- Whole Building Design Guide has compiled a webinar series on using the Energy Sales Agreement (ESA) contracts
- ESAs are a federal specific type of ESPC which enable purchase of renewable electricity
- Analogous to a power purchase agreement (PPA)

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