U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Non-Technical Barriers to EE Technology Adoption in Data Center

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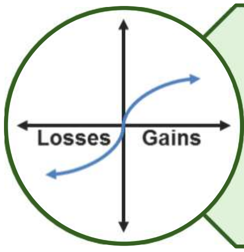
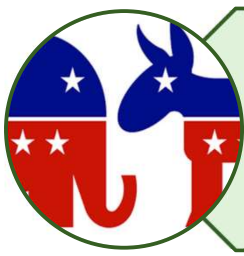
FEMP Federal Energy Management Program

Actors are influenced by more than money and engineering solutions



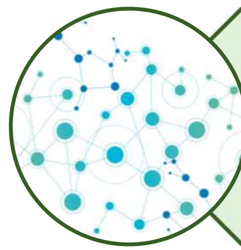
Behavioral Economics[1]

Economic Sociology[2]



Social Psychology[3,4]

Situational Factors[5,6]



Social Networks[7-9]

We should draw on EE decision-making literature for individuals and organizations

Individuals

- Theory of Planned Behavior [10,11]
  - Beliefs and attitudes
  - Behavior change in question
- Information Deficit Model [12,13]
  - Framing
  - Closing value-action gap
- Theory of Motivated Reasoning [14,15]
  - Biased information processing
  - Mitigating cognitive dissonance

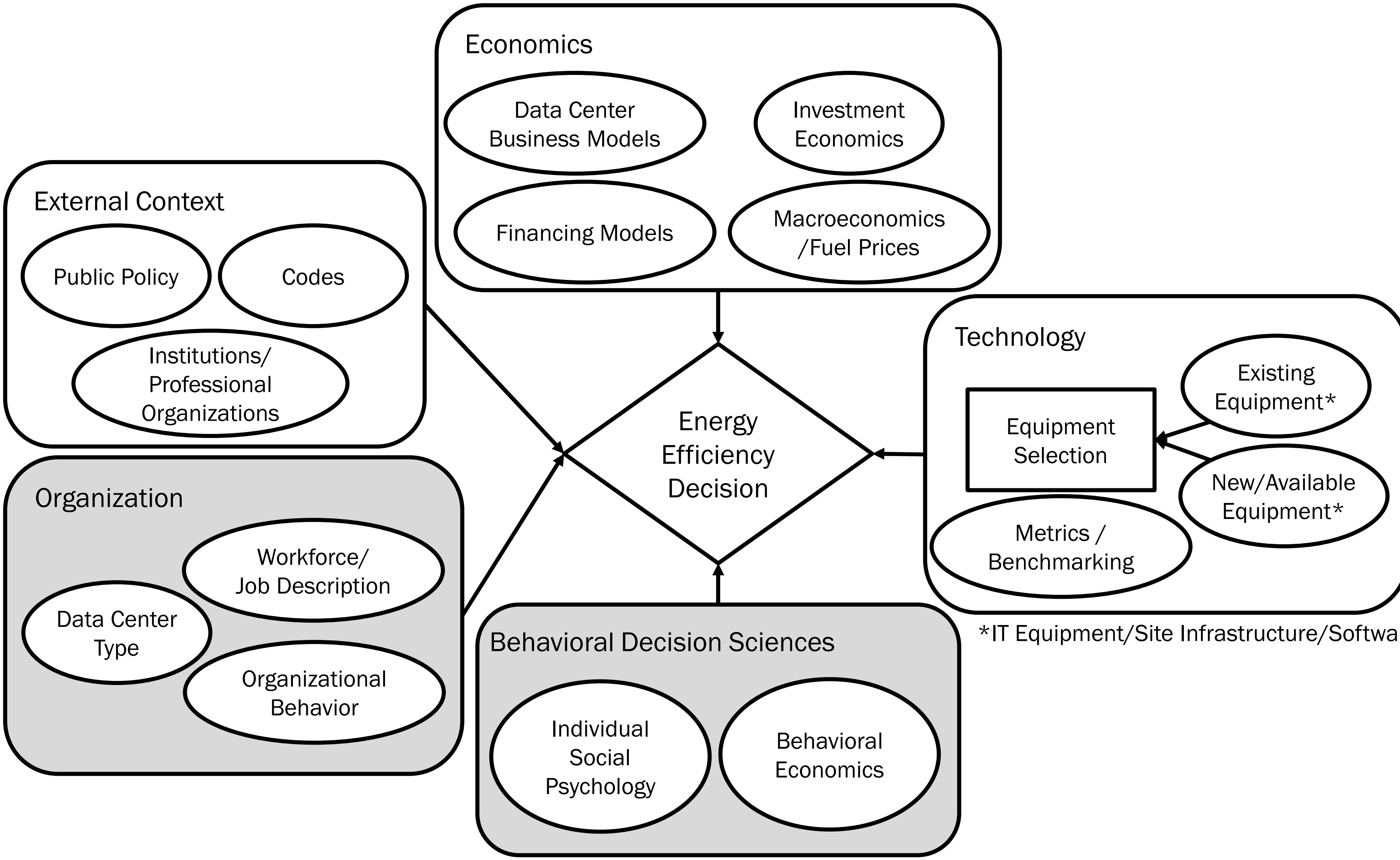
Organizations

- Capital Investment Theory [16-18]
  - Capital budgeting tools
  - Hidden/transaction costs
- Organizational Behavior Theory [19-22]
  - Power relationships
  - Organizational energy culture
  - EE investment link to core business

- **The Center of Expertise for Energy Efficiency in Data Centers (CoE) is completing a <u>two-phase</u> program of research for identifying key behavioral/organizational barriers**
- **Phase I: Literature Review**
  - 87 documents identified and reviewed, including academic publications, DOE/National Lab Reports, & professional organization materials (e.g. ASHRAE)
  - 26 unique journals including Science, Nature, Applied Energy, Energy Efficiency, and Energy Research and Social Science

Overview of Components to Energy Efficiency Decision-Making in Data Centers

Components to EE Decision-Making



*IT Equipment/Site Infrastructure/Software

High-Level Definitions

External Context

- Influences outside of the organization that directly or indirectly affect energy efficiency (EE) decisions within the organization
- Examples: Federal and state goals, DCEP, and Energy Act of 2020

Economics

- Influences can be both internal and external and are related to project budgeting and benefitting parties
- Examples: Capital constraints, utility incentives, fuel prices, and split incentives

Technology

- These include the decision-maker’s existing technology conditions and available options for new technologies, as well as the metrics and benchmarking available
- Examples: Discrepancies in PUE definitions, issues measuring energy consumption, and technology availability

Organization

- Influences related to the organization’s structure and data center type
- Examples: Corporate social responsibility, dedicated sustainability team, and trained data center operators

Behavior Decision Sciences

- Influences from the decision-maker’s own set of individual differences and decision-making heuristics
- Examples: Attitudes towards energy efficiency, uncertainty and perceived risk, and time discounting

Organizational Drivers and Barriers

Drivers	Barriers
System Efficiency Design and Operation Focus [23]	Lack of EE Champion [28,29]
Aligning Practice with Values [24,25]	Emphasis on Uptime and Reliability [30]
Meet CSR Goals, Demonstrate Excellence [26,27]	Low Strategic Priority [27,31,32]
	Internal Silos [33]
	Lack of Skilled, Interdisciplinary, and Diverse Workforce [34]

Reliability Emphasis Quote

"The extreme importance placed on uptime, reliability, and equipment redundancy results in data center staff being particularly averse to implementing new energy efficiency technologies or upgrades to their facilities. As one interview participant described, "No IT people get fired for not saving money, but they can get fired if their systems go down."

[30] Howard, A. J., & Holmes, J. (2012). Addressing Data Center Efficiency: Lessons Learned from Process Evaluations of Utility Energy Efficiency Programs. *Energy Efficiency*, 5(1), 137–48. https://doi.org/10.1007/s12053-011-9128-4.

Behavioral Drivers and Barriers

Drivers	Barriers
Ideology [32]	Low EE Salience in IT Staff [38,39]
Social Pressure [35,36]	Technical Risk Aversion [40,41]
Expertise and Individual Capacity [37,33]	Lack of Knowledge, Bounded Rationality [42]
	Time Discounting [27]

Salience Quotes

"An important stream of information about what is new and upcoming in the industry technology comes from our vendor partners and OEMs."

"I have a bookcase of magazines I don't have time to read."

"Participants also cautioned that while information about facility energy efficiency is usually reliable, data about the performance and energy use of IT equipment is 'kind of worthless' [since data centers are individualized facilities]."

[38] Klemick, H. , Kopits, E., & Wolverton, A. (2019). How Do Data Centers Make Energy Efficiency Investment Decisions? Qualitative Evidence from Focus Groups and Interviews. *Energy Efficiency, 12*(5), 1359-1377. https://doi.org/10.1007/s12053-019-09782-2.

Proposed Solutions for Overcoming Organizational and Behavioral Barriers

Organizational Solutions and Resources

Barrier	Interventions	Goals
Lack of EE Champion	• Identify change agents and IT-related change management [33]	• Change managers should possess a wide variety of skills, including familiarity with company, business processes and technical software expertise
Emphasis on Uptime and Reliability	• Consolidate facilities and IT hardware groups under one manager [33]	• Centralize capital expenditure decisions, leading to improvement in data center design and procurement process
Low Strategic Priority	• Communicate with stakeholders [33] • Institutionalize the change within the C-suite [33]	• An important step in any IT related change is to first assess the stakeholders involved and their likely motivations • Lasting change and project success are correlated with the degree to which change management is institutionalized within the IT organization's policies and culture
Internal Silos	• Host cross-team meetings [33] • Implement systems design thinking [33]	• Improve crosscutting collaboration • Think outside of the box: Identify the goal and then optimize all pieces of the system simultaneously
Lack of Skilled, Interdisciplinary, and Diverse Workforce	• Training [43] • Certification and professional recognition [43] • Reference best practices guides [43]	• Increase awareness of and expertise in working with energy-efficient products, technologies, and services • Provide professional credentials that have value in job market; create market differentiator for potential customers

Behavioral Solutions and Resources

Barrier	Interventions	Goals
Low EE Salience in IT Staff	• Institutionalize the change within the C-suite [33] • Certification and professional recognition [43] • Reference best practices guides [43] • Labeling [43]	• Lasting change and project success are correlated with the degree to which change management is institutionalized within the IT organization's policies and culture • Increase awareness of and expertise in working with energy-efficient products, technologies, and services • Create customer awareness of differences in EE among targeted products
Technical Risk Aversion	• Demonstration products and customer testimonials [43] • Educate other stakeholders as to how EE actions can actually bolster reliability and resiliency, and reduce O&M costs [25] • Initially prioritize low risk measures [25]	• Increase confidence in performance of products • Demonstrate a multitude of benefits from the EE measure • Demonstrate a proven process for implementing measures
Lack of Knowledge, Bounded Rationality	• Mass advertising [43] • Training [43]	• Increase awareness of products • Increase awareness of and expertise in working with energy-efficient products, technologies, and services
Time Discounting	• Bulk procurement and purchases [43] • Consider life-cycle cost analysis in decision-making [23]	• Increase demand quickly and seek lower prices due to economies of scale • Life-cycle cost analysis can allow for the inclusion of energy price volatility, non-energy benefits, and product disposal

Future Research on Non-Technology Barriers to EE in Data Centers

Next Steps

- **CoE Phase II:** Interviewing data center owners and operators, vendors, academics, and other EE experts to identify (1) the prevalence of barriers identified in the literature across data center decision-makers and (2) effective policies for addressing these barriers

- **Areas for Future ARPA-E Collaboration:**
  - In parallel to technology R&D, there should be a dedicated research track to understanding the mechanisms to achieving speed and scale
  - Case studies could include semi-structured interviews with data center operators regarding the non-technology obstacles they faced when implementing the new technology

References

1. C. Wilson and H. Dowlatabadi, "Models of Decision Making and Residential Energy Use," *Annu. Rev. Environ. Resour.*, vol. 32, no. 1, pp. 169–203, 2007.
2. M. Granovetter, "Economic action and social structure: the problem of embeddedness," *Am. J. Sociol.*, vol. 91, no. 3, pp. 481–510, 1985.
3. E. U. Weber and P. C. Stern, "Public understanding of climate change in the United States.," *Am. Psychol.*, vol. 66, no. 4, pp. 315–328, 2011.
4. A. Bandura, "Self-Efficacy Mechanism in Human Agency," vol. 37, no. 2, pp. 122–147, 1982.
5. P. W. Schultz, S. Oskamp, and T. Mainieri, "Who recycles and when? A review of personal and situational factors," *J. Environ. Psychol.*, vol. 15, no. 2, pp. 105–121, 1995.
6. S. Geller *et al.,* "Prompting a consumer behavior for pollution control" *Journal of Applied Behavior Analysis*. pp. 367-376.
7. D. Noll, C. Dawes, and V. Rai, "Solar community organizations and active peer effects in the adoption of residential PV," *Energy Policy*, vol. 67, pp. 330–343, 2014.
8. H. Allcott, "Social norms and energy conservation," *J. Public Econ.*, vol. 95, no. 9–10, pp. 1082–1095, 2011.
9. G. Peschiera and J. E. Taylor, "The impact of peer network position on electricity consumption in building occupant networks utilizing energy feedback systems," *Energy Build.*, vol. 49, pp. 584–590, 2012.
10. I. Ajzen, "The theory of planned behavior," *Orgnizational Behav. Hum. Decis. Process.*, vol. 50, pp. 179–211, 1991.
11. P. C. Stern, "Toward a Coherent Theory of Environmentally Significant Behavior," *J. Soc. Issues*, vol. 56, no. 3, pp. 407–424, 2000.
12. P. Sturgis and N. Allum, "Science in Society: Re-Evaluating the Deficit Model of Public Attitudes," *Public Underst. Sci.*, vol. 13, no. 1, pp. 55–74, 2004.
13. P. S. Hart and E. C. Nisbet, "Boomerang Effects in Science Communication: How Motivated Reasoning and Identity Cues Amplify Opinion Polarization About Climate Mitigation Policies," *Communic. Res.*, vol. 39, no. 6, pp. 701–723, 2012.
14. Z. Kunda, "The case for motivated reasoning.," *Psychol. Bull.*, vol. 108, no. 3, pp. 480–498, 1990.
15. C. S. Taber and M. Lodge, "Motivated Skepticism in the Evaluation of Political Beliefs," *Am. J. Pol. Sci.*, vol. 50, no. 3, pp. 755–769, 2006.
16. S. T. Anderson and R. G. Newell, "Information programs for technology adoption: The case of energy-efficiency audits," *Resour. Energy Econ.*, vol. 26, pp. 27–50, 2004.
17. A. B. Jaffe and R. N. Stavins, "The energy-effincency gap What does it mean?," *Energy Policy*, vol. 22, no. 10, pp. 804–810, 1994.
18. R. J. Sutherland, "Market Barriers to Energy-Efficiency Investments," *Energy J.*, vol. 12, no. 3, pp. 15–34, 1991.
19. S. Sorrell *et al.*, "Reducing barriers to energy efficiency in public and private organisations," 2000.
20. C. Cooremans, "Make it strategic! Financial investment logic is not enough," *Energy Effic.*, vol. 4, no. 4, pp. 473–492, 2011.
21. P. C. Stern, "What psychology knows about energy conservation.," *Am. Psychol.*, vol. 47, no. 10, pp. 1224–1232, 1992.
22. H. L. F. De Groot, E. T. Verhoef, and P. Nijkamp, "Energy saving by firms: Decision-making, barriers and policies," *Energy Econ.*, vol. 23, no. 6, pp. 717–740, 2001.
23. Shamshoian, Gary, Blazek, Michele, and Naughton, Phil. "High-Tech Means High-Efficiency: The Business Case for Energy Management in High-Tech Industries." LBNL Report. (November 2005). https://escholarship.org/uc/item/429064xw
24. Molla, Alemayehu, Siddhi Pittayachawan, Brian Corbitt, and Hepu Deng. "An International Comparison of Green IT Diffusion." International Journal of E-Business Management 3 (October 1, 2009): 3–23. https://doi.org/10.3316/IJEBM0302003.
25. Center of Expertise (CoE) for Energy Efficiency in Data Centers. "Building the Business Case for Energy Efficiency in Data Centers." (July 2020).
26. Adjei, J. K., Adams, S., & Mamattah, L. (2021). Cloud computing adoption in Ghana; accounting for institutional factors. Technology in Society, 65, 101583.
27. Hanus, Nichole, Gabrielle Wong-Parodi, Mitchell J. Small, and Iris Grossmann. "The Role of Psychology and Social Influences in Energy Efficiency Adoption." Energy Efficiency 11, no. 2 (February 2018): 371–91. https://doi.org/10.1007/s12053-017-9568-6.
28. Seifert, Christin. "The Barriers for Voluntary Environmental Management Systems—The Case of EMAS in Hospitals." Sustainability 10, no. 5 (May 2018): 1420. https://doi.org/10.3390/su10051420.
29. Sartor, Dale, and Steve Greenberg. "How to Save Money In Your Small Data Center." Workshop presented at the Energy Exchange, Cleveland, Ohio, August 20, 2018.
30. Howard, A. J., and Jennifer Holmes. "Addressing Data Center Efficiency: Lessons Learned from Process Evaluations of Utility Energy Efficiency Programs." Energy Efficiency 5, no. 1 (February 1, 2012): 137–48. https://doi.org/10.1007/s12053-011-9128-4.
31. Maiorano, John. "Beyond Technocracy: Forms of Rationality and Uncertainty in Organizational Behaviour and Energy Efficiency Decision Making in Canada." Energy Research & Social Science 44 (October 1, 2018): 385–98. https://doi.org/10.1016/j.erss.2018.05.007.
32. Kaplowitz, Michael D., Laurie Thorp, Kayla Coleman, and Felix Kwame Yeboah. "Energy Conservation Attitudes, Knowledge, and Behaviors in Science Laboratories." Energy Policy, Special Section: Past and Prospective Energy Transitions - Insights from History, 50 (November 1, 2012): 581–91. https://doi.org/10.1016/j.enpol.2012.07.060.
33. Schuetz, Nicole, Anna Kovaleva, and Jonathan Koomey. "EBay Inc.: A Case Study of Organizational Change Underlying Technical Infrastructure Optimization," n.d., 27.
34. Sverdlik, Yevgeniy. "Google Data Center Execs Say Industry Headed for Talent Crisis." Data Center Knowledge. (March 2018). https://www.datacenterknowledge.com/google-alphabet/google-data-center-execs-say-industry-headed-talent-crisis
35. Cresswell, Kathrin, and Aziz Sheikh. "Organizational Issues in the Implementation and Adoption of Health Information Technology Innovations: An Interpretative Review." International Journal of Medical Informatics 82, no. 5 (May 1, 2013): e73–86. https://doi.org/10.1016/j.ijmedinf.2012.10.007.
36. Johnson, Keith. (2011). Guide to Adaptive Challenges and Action Learning. https://www.cultivatingleadership.com/resource/guide-to-adaptive-challenges-and-action-learning
37. König, Werner. "Energy Efficiency in Industrial Organizations––A Cultural-Institutional Framework of Decision Making." Energy Research & Social Science 60 (February 1, 2020): 101314. https://doi.org/10.1016/j.erss.2019.101314.
38. Klemick, Heather, Elizabeth Kopits, and Ann Wolverton. "How Do Data Centers Make Energy Efficiency Investment Decisions? Qualitative Evidence from Focus Groups and Interviews." Energy Efficiency 12, no. 5 (June 1, 2019): 1359–77. https://doi.org/10.1007/s12053-019-09782-2.
39. Lansing, Nicholas. "The Modern Data Center." Forbes, n.d. https://branden.biz/wp-content/uploads/2020/03/vertiv-forbes-modern-data-center-report.pdf.
40. Loper, Joe, and Sara Parr. "Energy Efficiency in Data Centers: A New Policy Frontier," n.d., 20.
41. Palm, Jenny, and Patrik Thollander. "An Interdisciplinary Perspective on Industrial Energy Efficiency." Applied Energy 87, no. 10 (October 1, 2010): 3255–61. https://doi.org/10.1016/j.apenergy.2010.04.019.
42. Bennett, Drew, and Pierre Delforge. "Small Server Rooms, Big Energy Savings: Opportunities and Barriers to Energy Efficiency on the Small Server Room Market," 2012.
43. York, Dan, Bastian, Hannah, Relf, Grace, and Armann, Jennifer. "Transforming Energy Efficiency Markets: Lessons Learned and Next Steps." Transforming Markets ACEEE. (December