U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

FEMP Federal Energy Management Program

United States Data Center Energy Usage Report

December 6, 2016

Arman Shehabi, Ph.D.

Research Scientist

Lawrence Berkeley National Laboratory

Before We Begin

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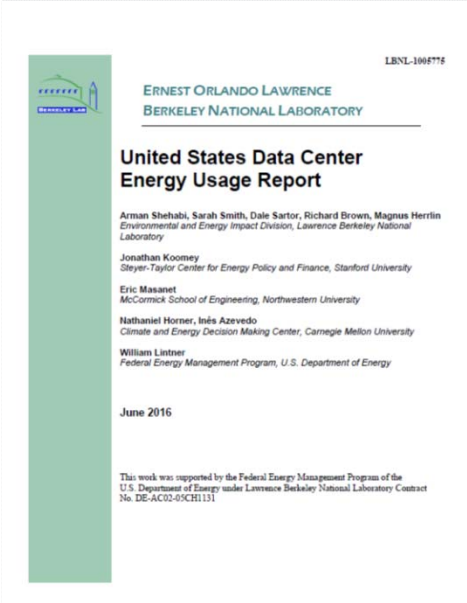
- All lines have been muted, to be unmuted or to ask a question, please go to your meeting controls panel and raise your hand
- To submit questions via chat, click the chat button in the top right of your screen and a text box will appear in the bottom right. Please select to send your message to Elena Meehan, enter text, and press enter.
- Slides will be posted at datacenterworkshop.lbl.gov
- Attendees can receive a certificate of completion by filling out an evaluation form. Link is provided at the end of the presentation and will also be sent to you in a follow-up email.

Acknowledgments

- Report Authors:

Arman Shehabi	Environmental and Energy Impact Division, Lawrence Berkeley National Laboratory
Sarah Smith	
Richard Brown	
Dale Sartor	
Mangus Herrlin	
Jonathan Koomey	Steyer-Taylor Center for Energy Policy and Finance, Stanford University
Eric Masanet	McCormick School of Engineering, Northwestern University,
Nathaniel Horner	Climate and Energy Decision Making Center, Carnegie Mellon University
Inês Azevedo	
William Lintner	Federal Energy Management Program, U.S. Department of Energy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June 2016

This work was supported by the Federal Energy Management Program of the U.S. Department of Energy under Lawrence Berkeley National Laboratory Contract No. DE-AC02-05CH1131

- Report Reviewers (industry, advocates, government)
- DOE Federal Energy Management Program

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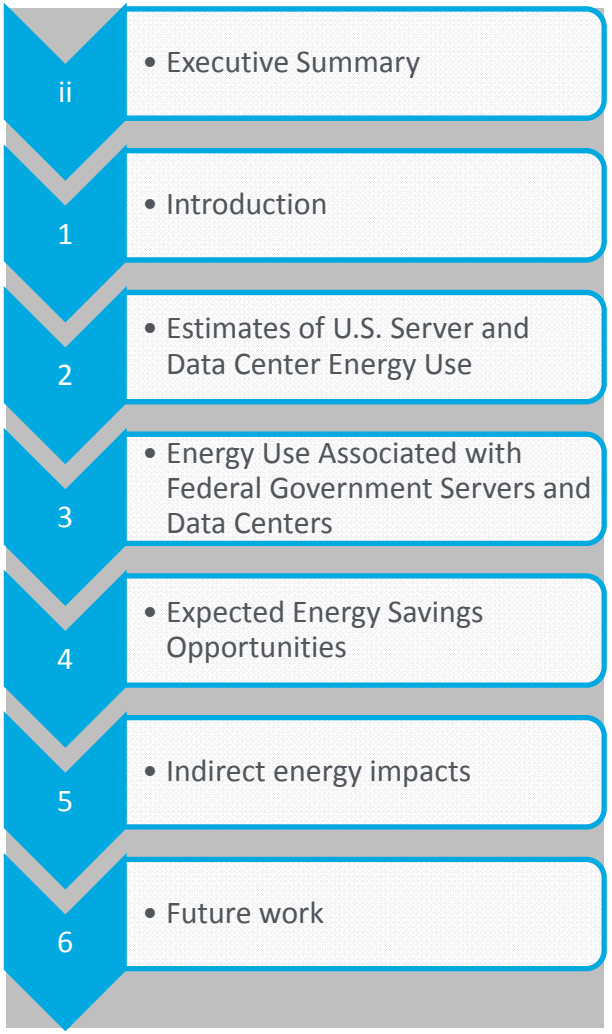
Project Overview of Data Center Report

- Current and projected data center energy use through 2020
- Includes main authors of the 2007 Data Center Report to Congress
- Additional chapter on “indirect effects” (e.g. telework)
- Draft report sent out for review to corroborate assumptions
  - Reviewers included industry and advocates
  - Comments from about 30 companies
  - Nearly 300 individual comments



Conventional Understanding of Data Centers

- Size range from “closets” to “hyperscale” facilities
- Experiencing major growth over last decade
- High building energy intensity (>100 W/ft2)
- Nearly 2% of U.S. electricity consumption
- Some server racks now designed for >30 kW
- Power and cooling constraints in existing facilities

THE CLOUD FACTORIES

Power, Pollution and the Internet

The New York Times

Ethan Pines for The New York Times

Data centers are filled with servers, which are like bulked-up desktop computers, minus screens and keyboards, that contain chips to process data.

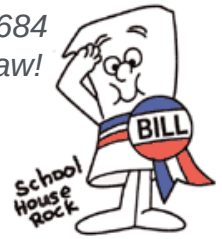
By JAMES GLANZ

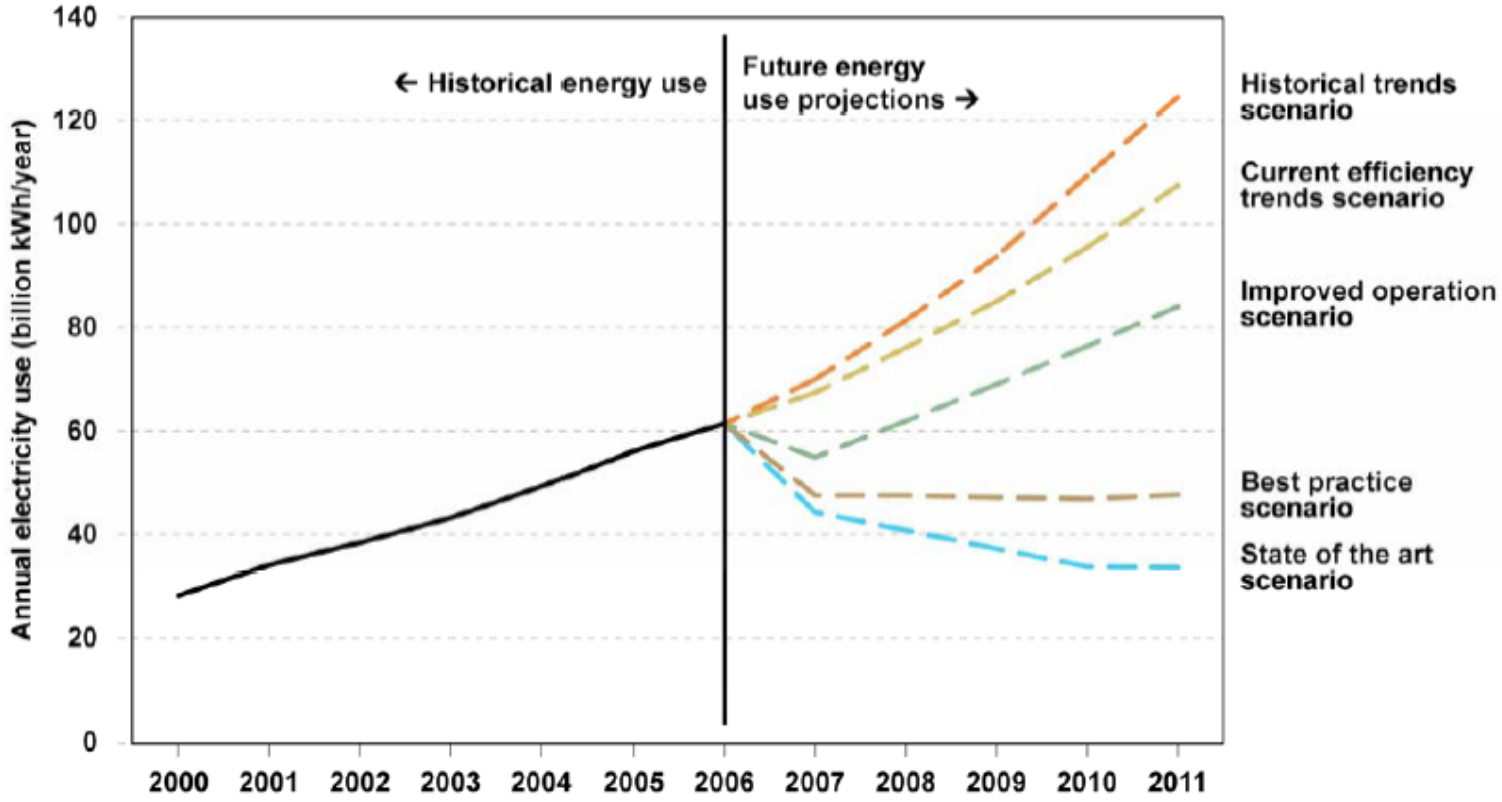
Published: September 22, 2012 | 305 Comments

Data center energy projections in 2007

Report to Congress on Server and Data Center Energy Efficiency Public Law 109-431

Senate Bill 3684 becomes a law!

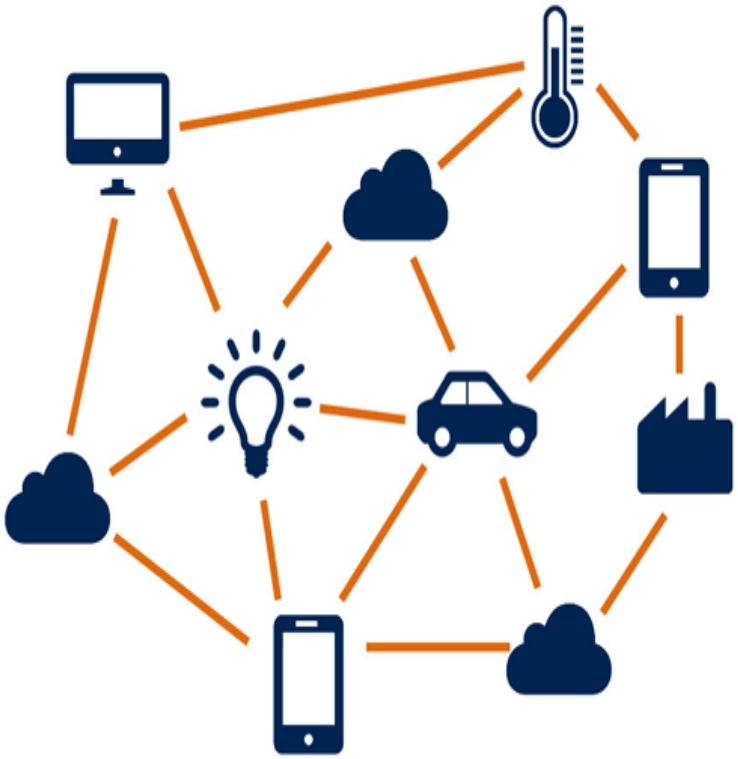




Brown et al., 2007, *Report to Congress on Server and Data Center Energy Efficiency Public Law 109-431*

Data Center Landscape Different than 2007

- Emergence of cloud computing and social media
  - IP traffic increasing 20% annually
- Dominance of “hyperscale” data centers
- Growth in data storage
  - 20x increase since 2007
- Internet of Things capabilities
- New IT equipment
  - “Unbranded” ODM servers
  - Solid state hard drives
  - Faster network ports



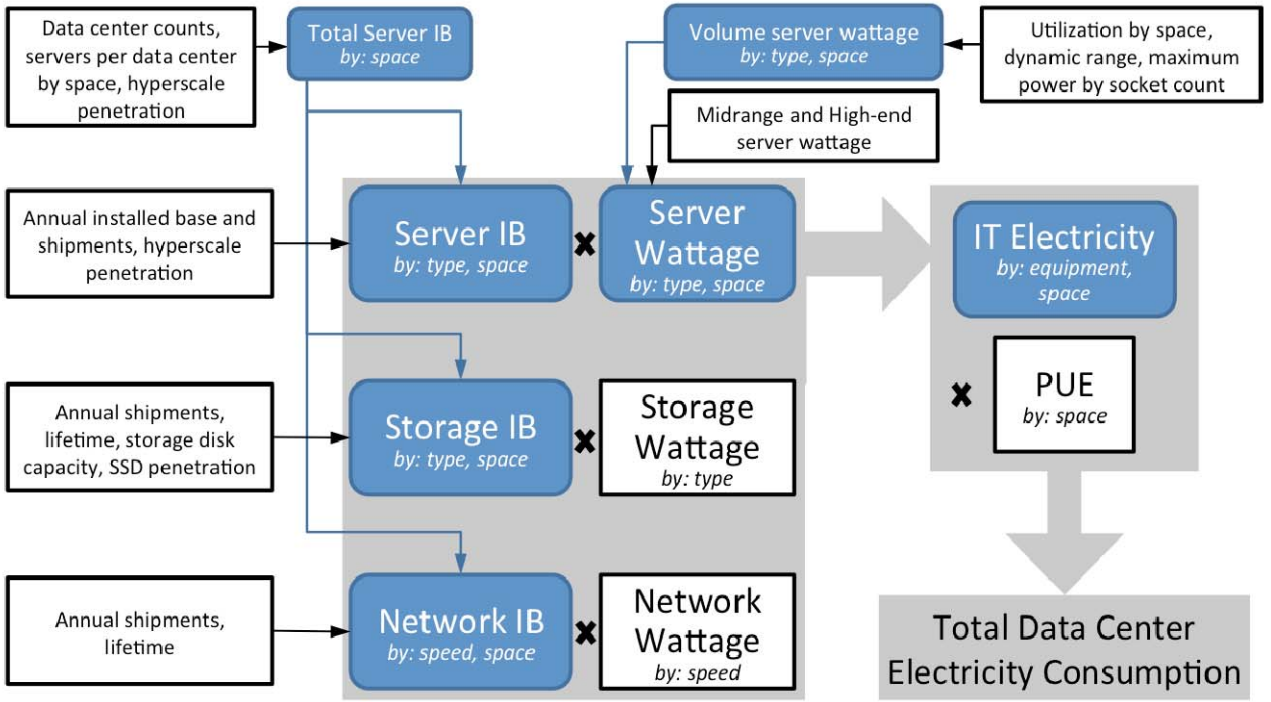
Data Center Market Assessment: Objective

Update model inputs to maintain accuracy and relevance…

- Characterize current market and trends
- Project energy demand growth
- Identify potential efficiency opportunities
- Obtain industry input and collaboration
- Establish an updatable Berkeley data center energy model
    - Self-contained, parametric modeling framework with improved resolution (i.e., “dials to turn”)

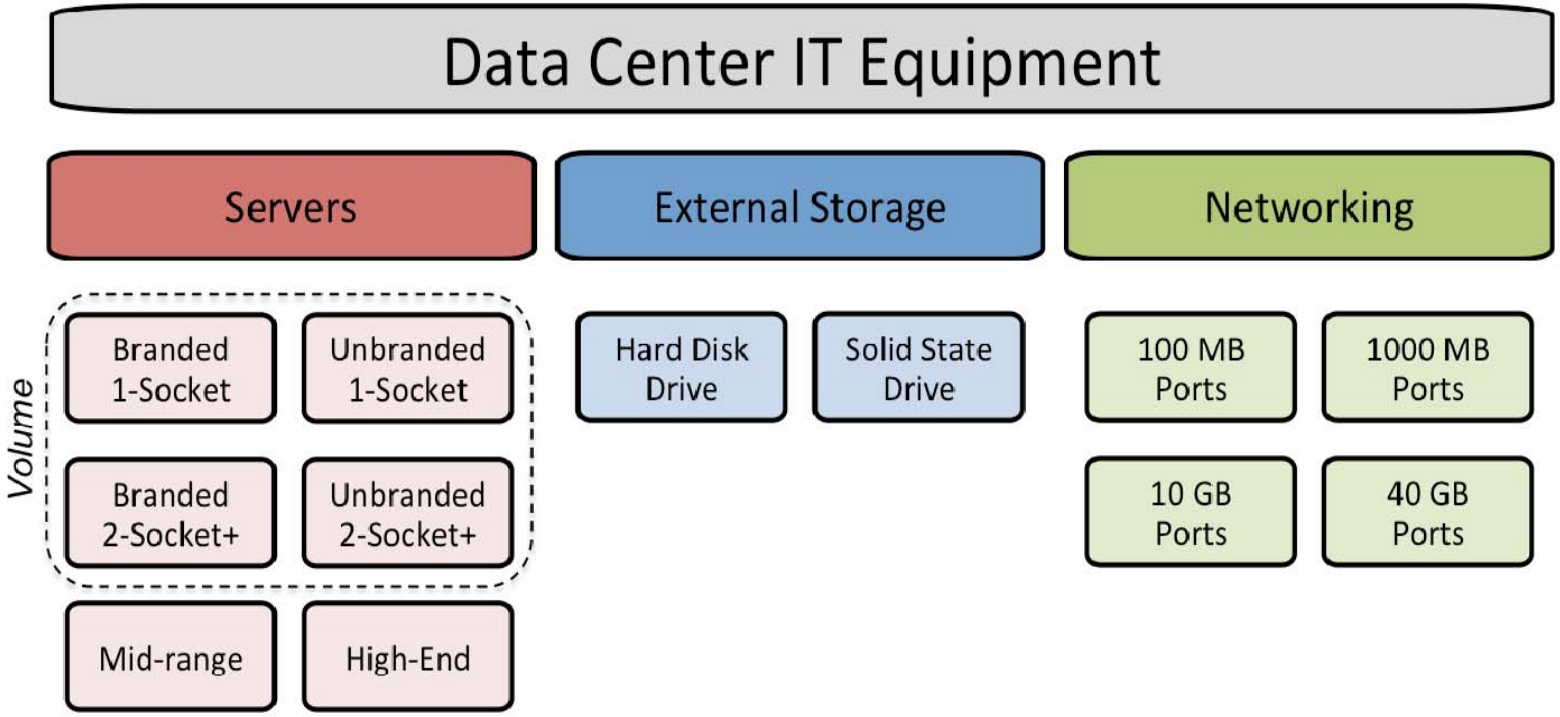
Research Approach

- Leverage existing data center model, and update with
  - IDC, SPEC, ITI data for IT equipment characteristics & shipments
  - IT & infrastructure assumptions from lit review, industry feedback
- Disaggregate “product” data center operations
- Energy projections under four scenarios
  - Current Trends
  - Improved Operation
  - Best Practices
  - Hyperscale Shift

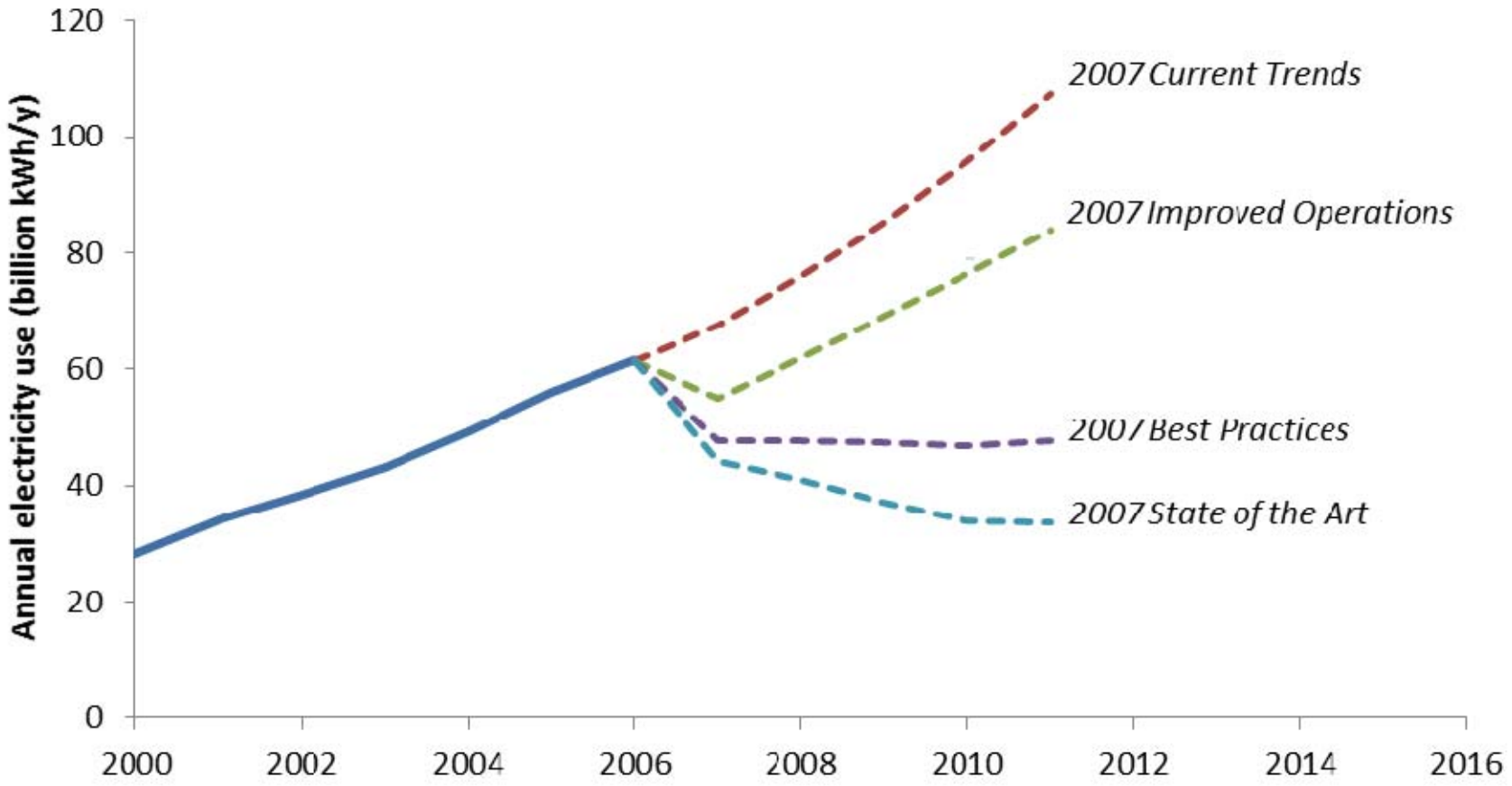


Research Approach

- Expand IT equipment categories in current Berkeley data center energy model

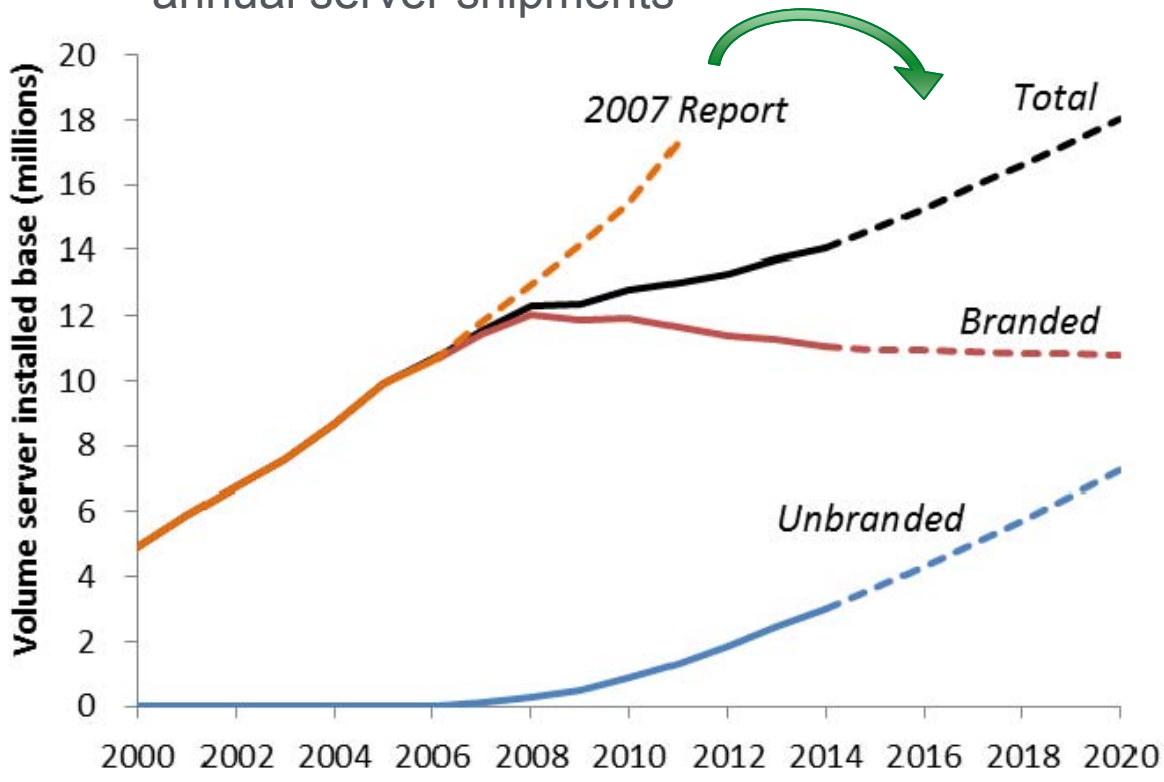


Energy Use Estimates

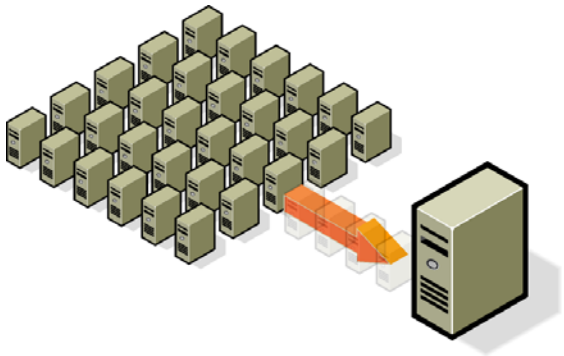


Server Shipments: Growth of the Unbranded

- Nearly all server shipment growth since 2010 occurred in servers destined for large hyperscale data centers
  - Hyperscale data centers typically operate more efficiently
  - Growing percentage of overall data center activity
  - Increase **virtualization** and **consolidation** has tempered increase in annual server shipments

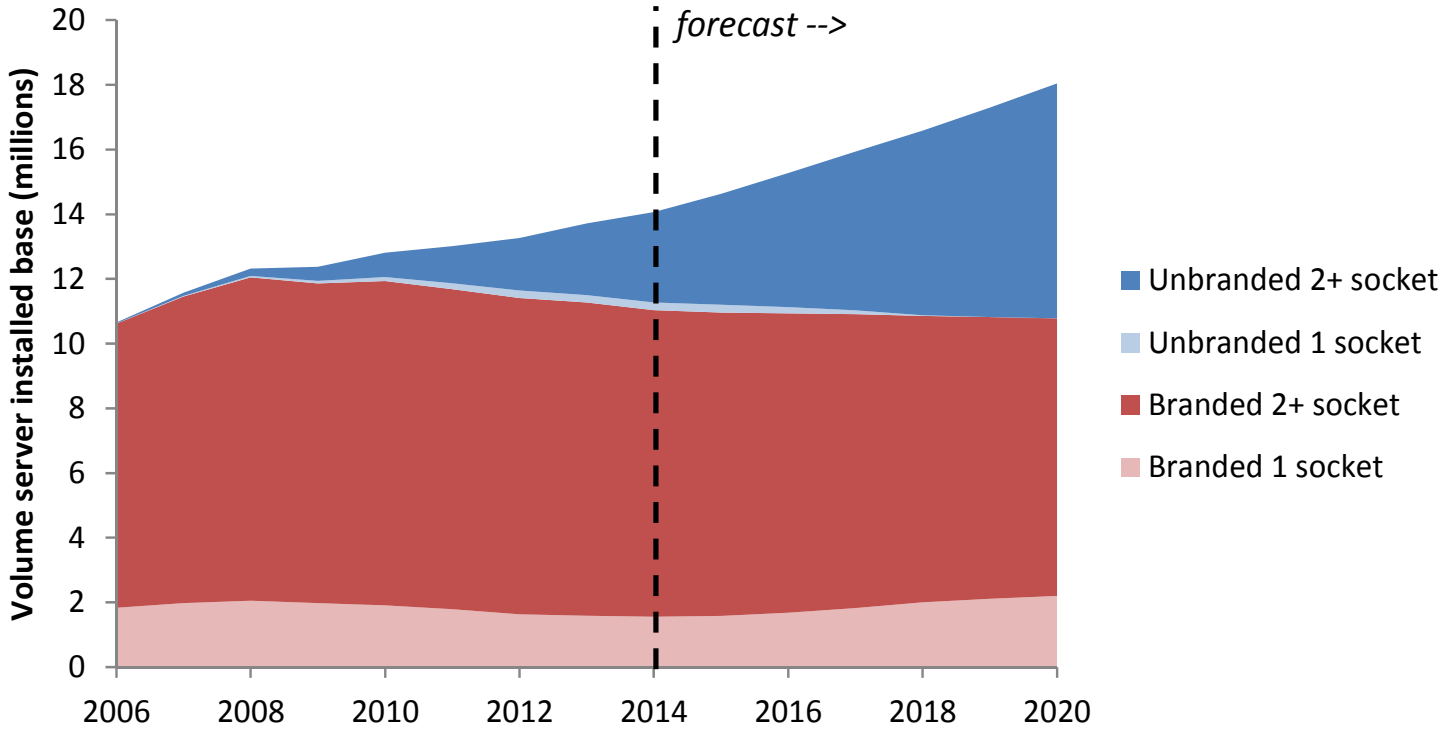


Large reduction in physical server demand within data centers



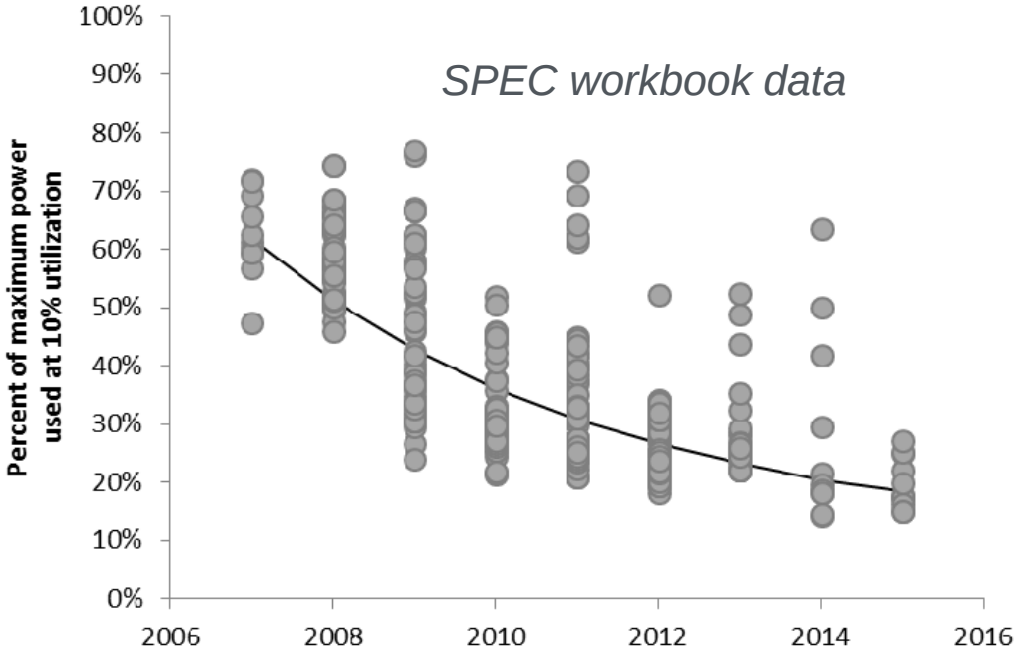
Server Shipments: 2-sockets dominate

- Nearly all unbranded servers are shipped with 2 sockets (i.e., 2-processor servers)
  - Single-socket server base remains at a constant level, but a diminishing fraction of the market



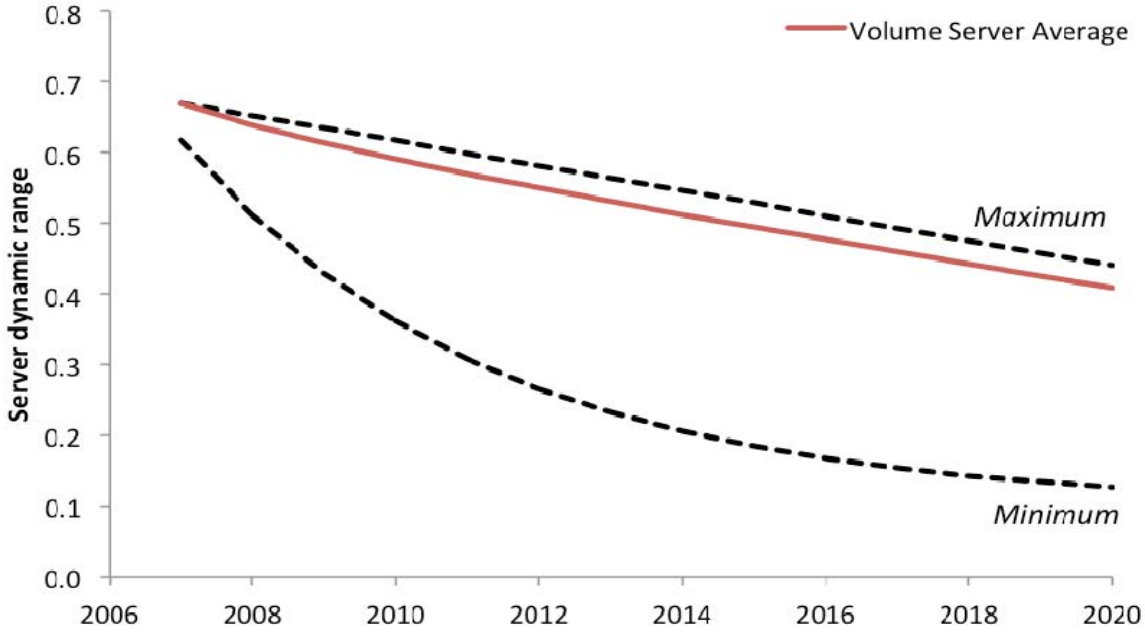
Server Energy Use: Power Scaling Ability

- Servers are improving in power scaling ability
  - Servers typically operate at 10-50% utilization
  - Idle servers often consume 50%–60% of power at full load
  - Increased power scaling reduces average power demand
- Huge improvements in “tested” power scaling, but different than real-world applications



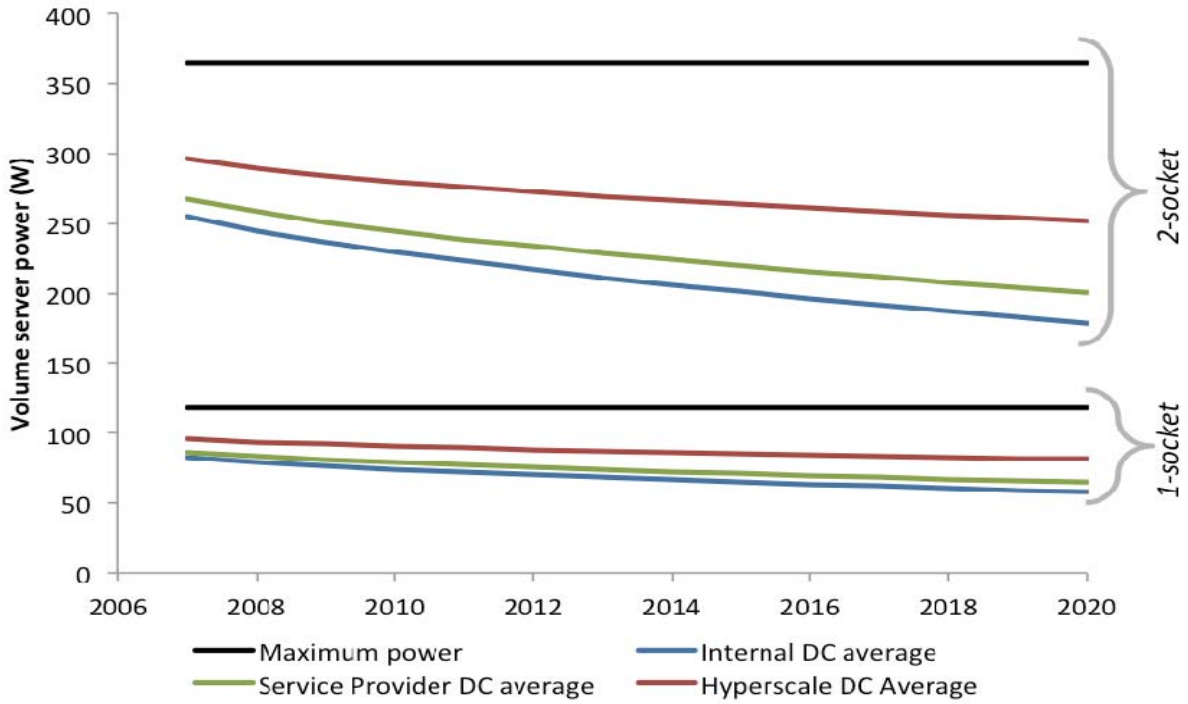
Server Energy Use: Range of Power Scaling

- Dynamic range of server power scaling added to model
  - Best scaling (min value) improvement represented by SPEC
  - Worst scaling (max value) improvement from historical data
- In report, 90/10 max/min mix is applied to installed base



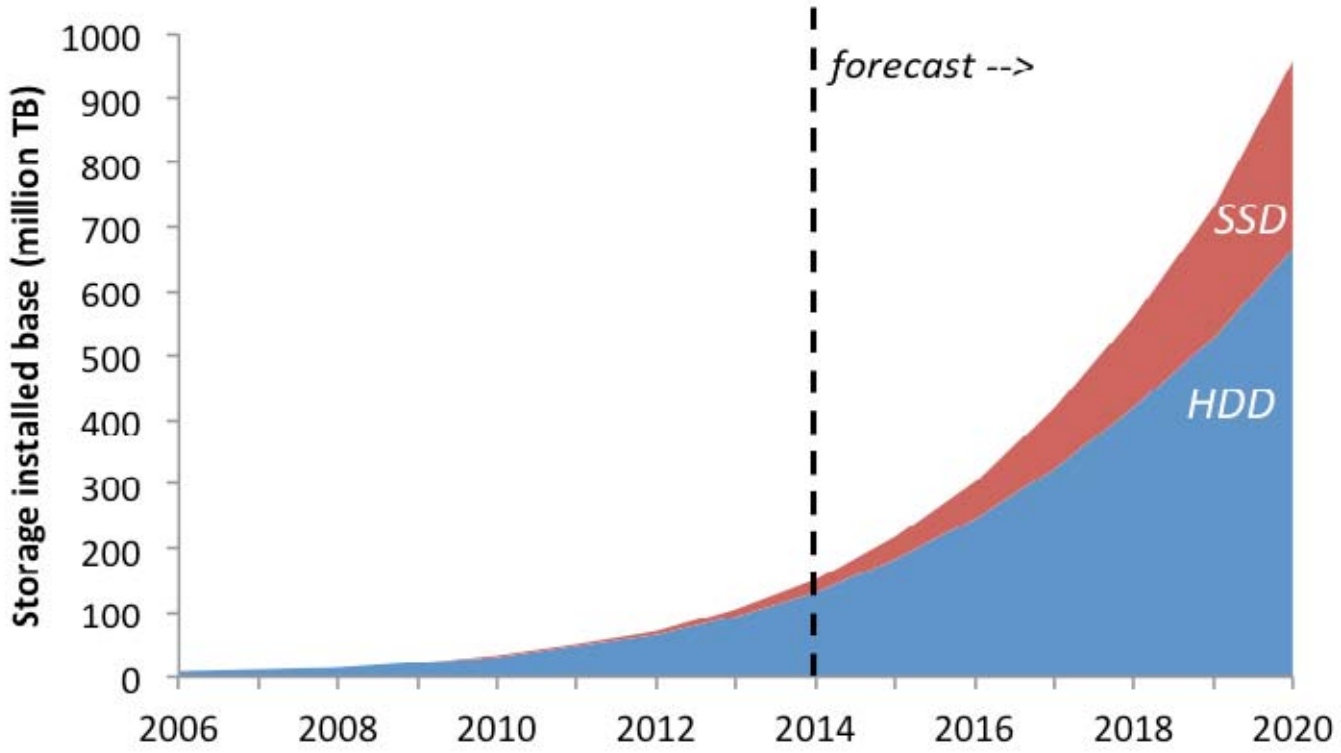
Server Energy Use at Average Utilization

- Max power estimates based on entries in SERT data base
- Steady max power over time assumed from historical observation
- Accounts for utilization differences in internal, service, and hyperscale data centers



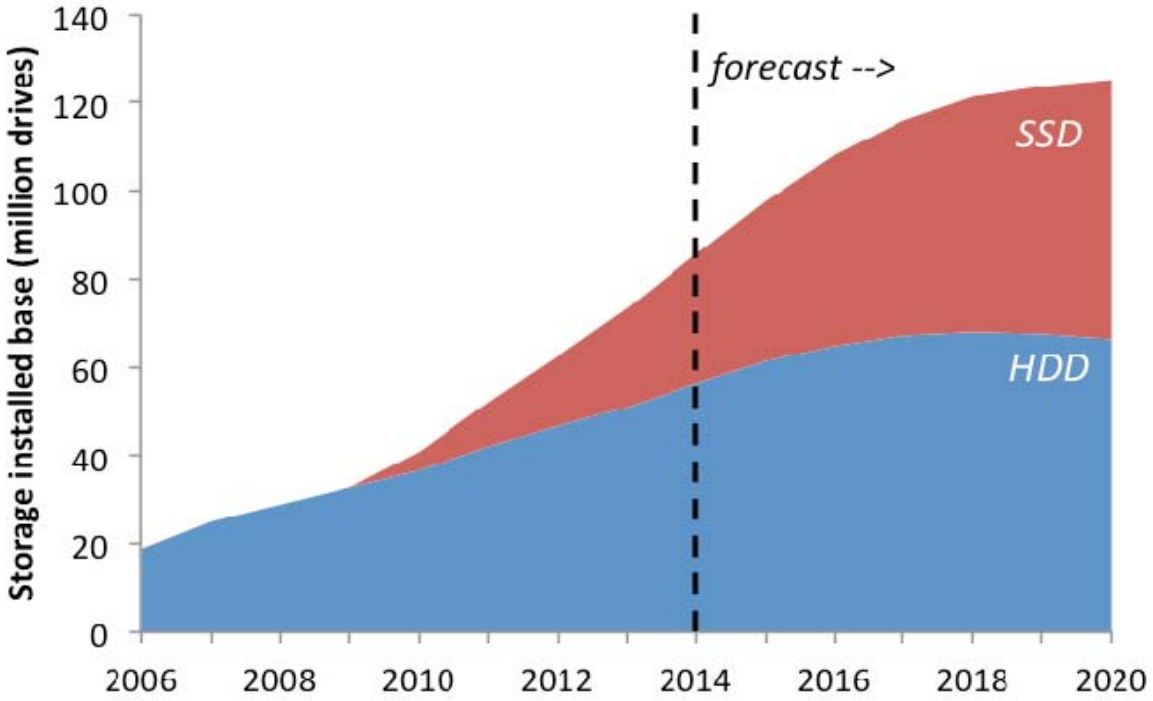
Storage Shipments: Growth in Capacity

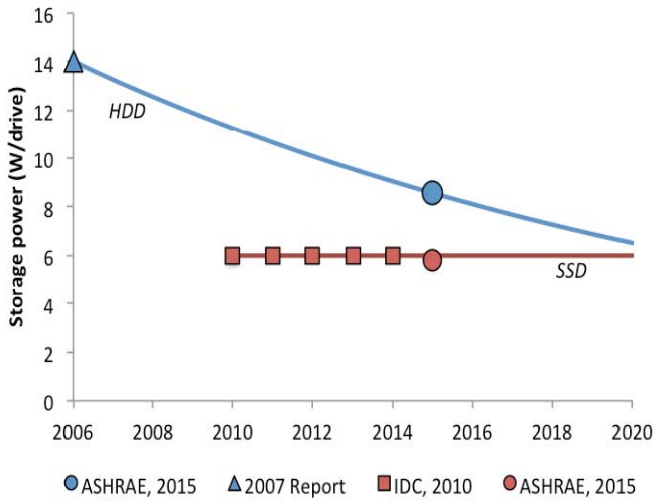
- Current storage a 20x increase since 2007
- Nearly a zettabyte (ZB) of storage capacity by 2020!



Storage Shipments: Installed Base of Drives

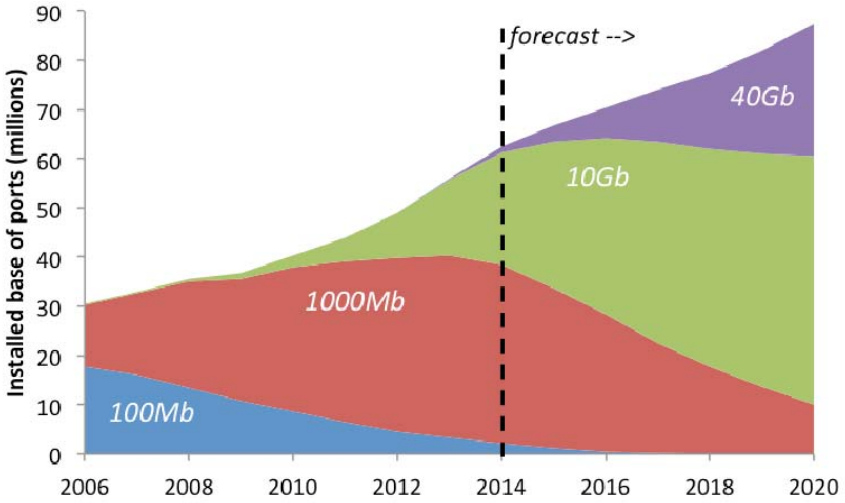
- Increased drive capacity (TB/drive) outpacing TB shipments
- Average drive efficiency continues to improve

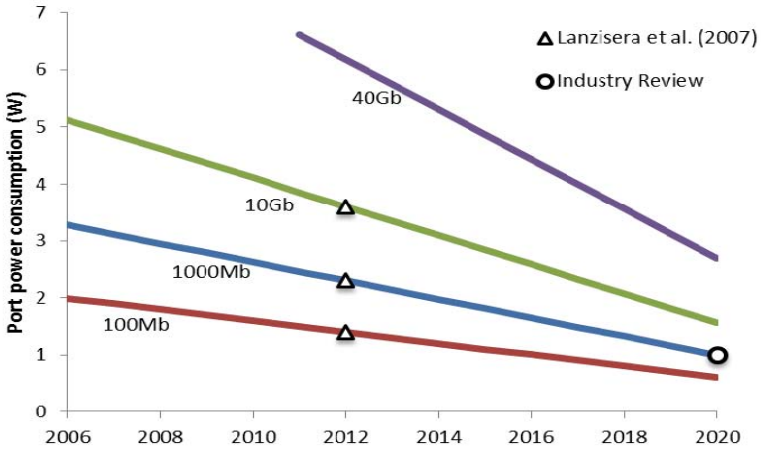




Network Equipment

- Network scope limited to Level 2/Level 3 network ports in data centers
- Shift to faster port speeds
- Drastic improvements in per port efficiency



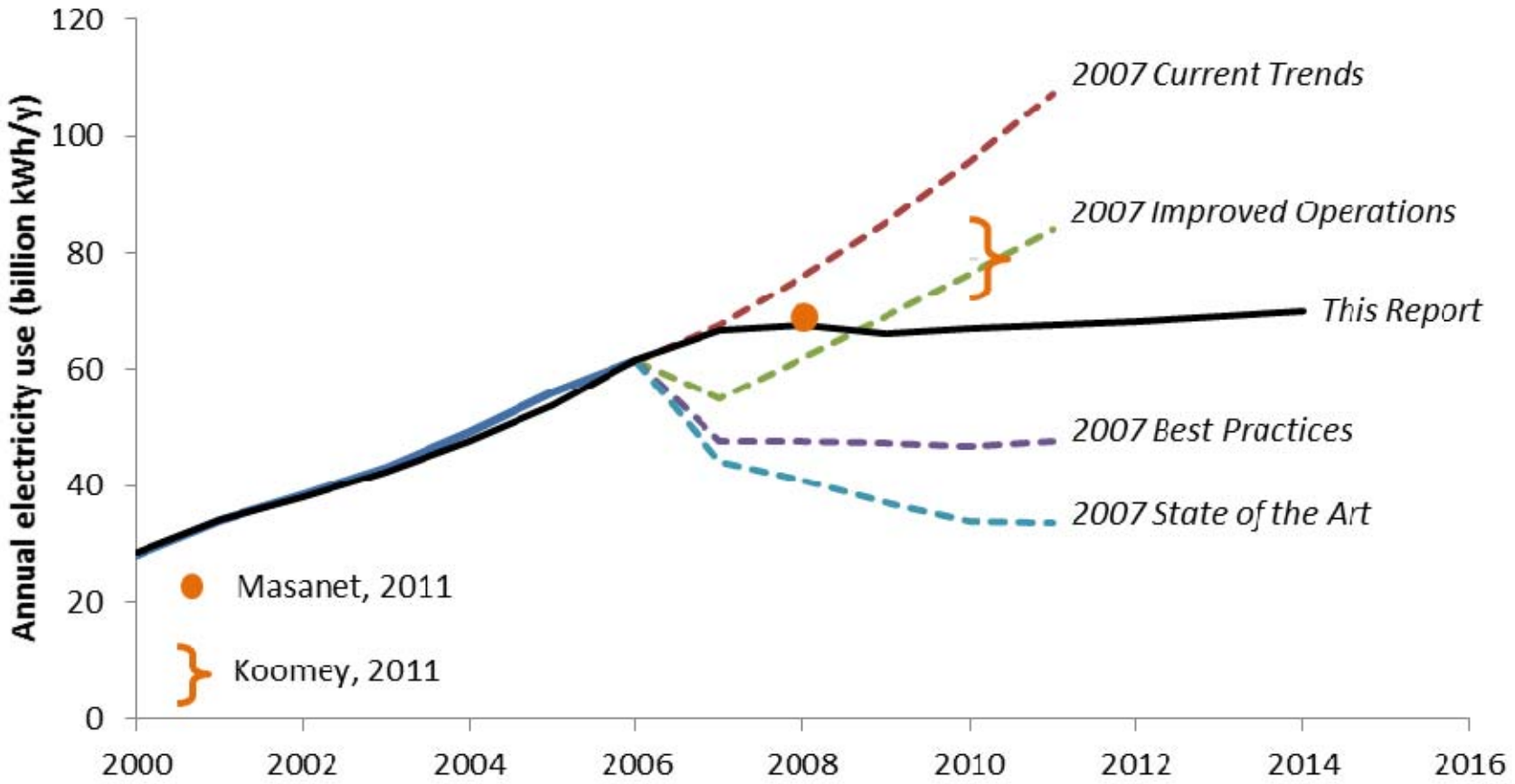


Infrastructure Energy: Power Use Effectiveness

- PUE values varies by data center size
- PUE values, anticipated to improve by 1% per year through 2020, except for closets

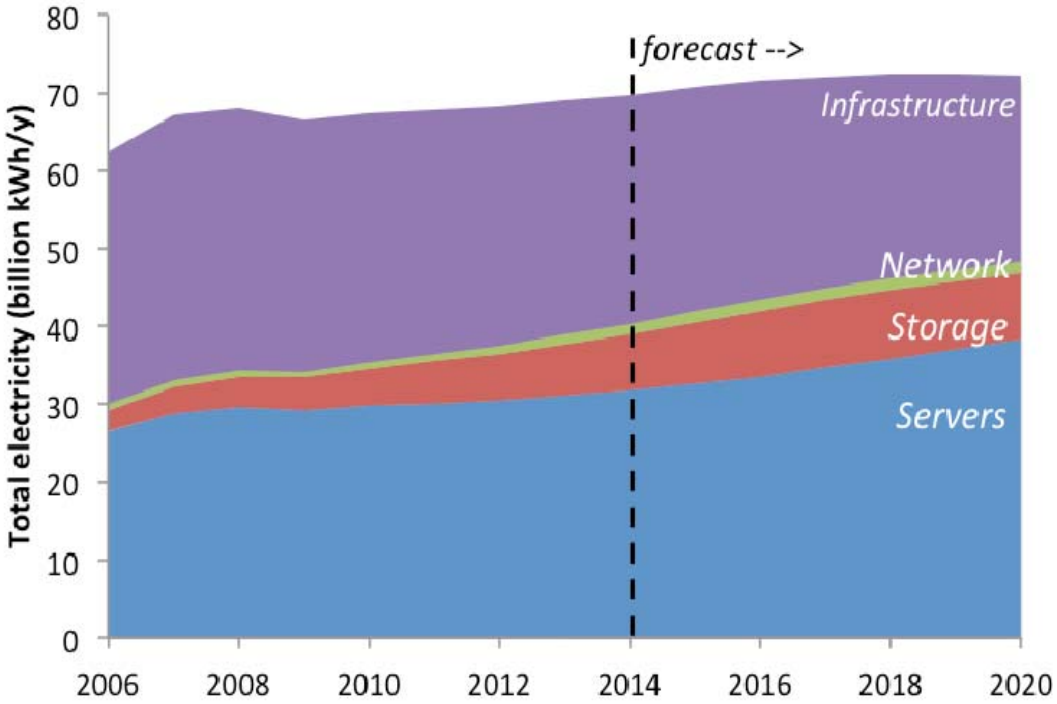
Space Type	Typical Size (ft^2)	Average PUE
Closet	<100	2.5
Room	100	2.1
Localized	500-2K	2
Midtier	2K-20K	2
High-end	20K-100K	1.5
Hyperscale	>100K	1.2

Energy Use Estimates



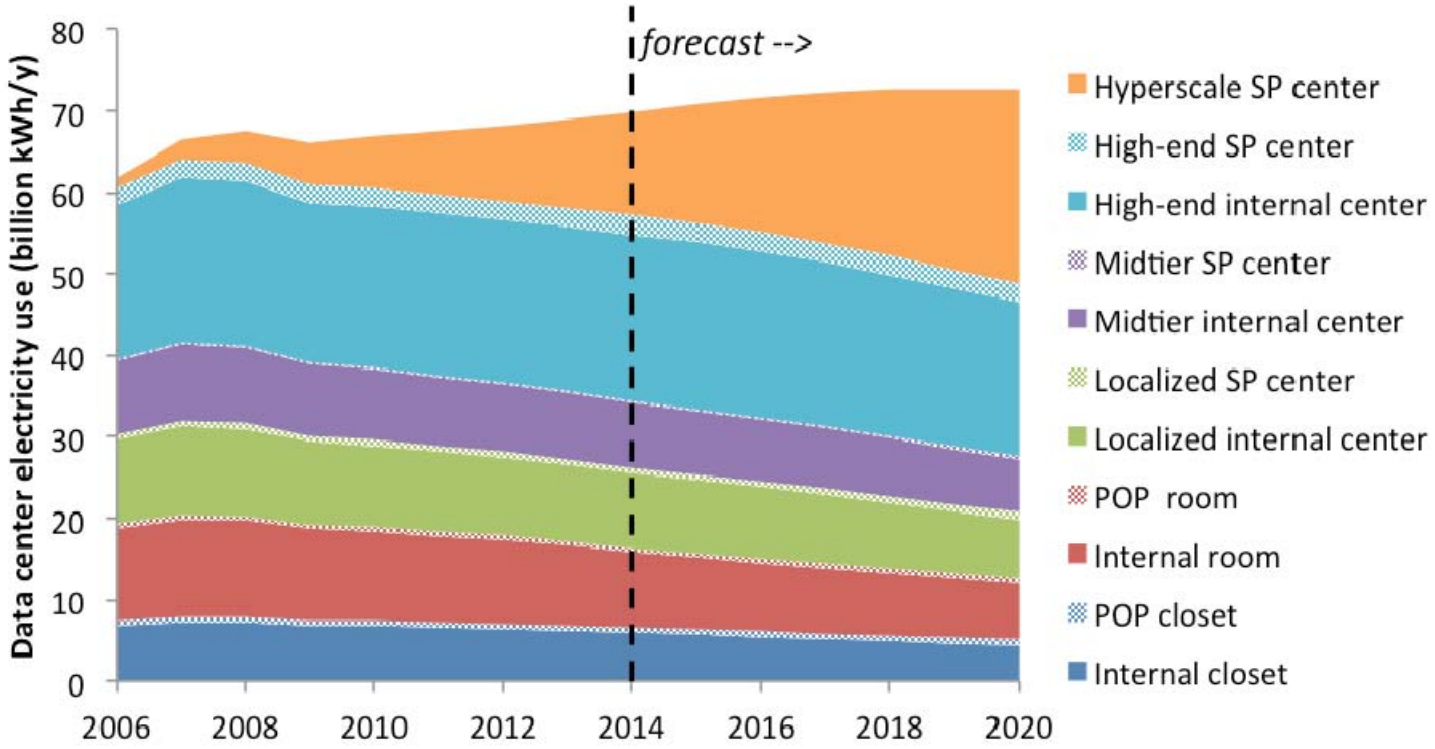
Energy Use Estimates by Component

- Data center energy use dominated by servers and infrastructure

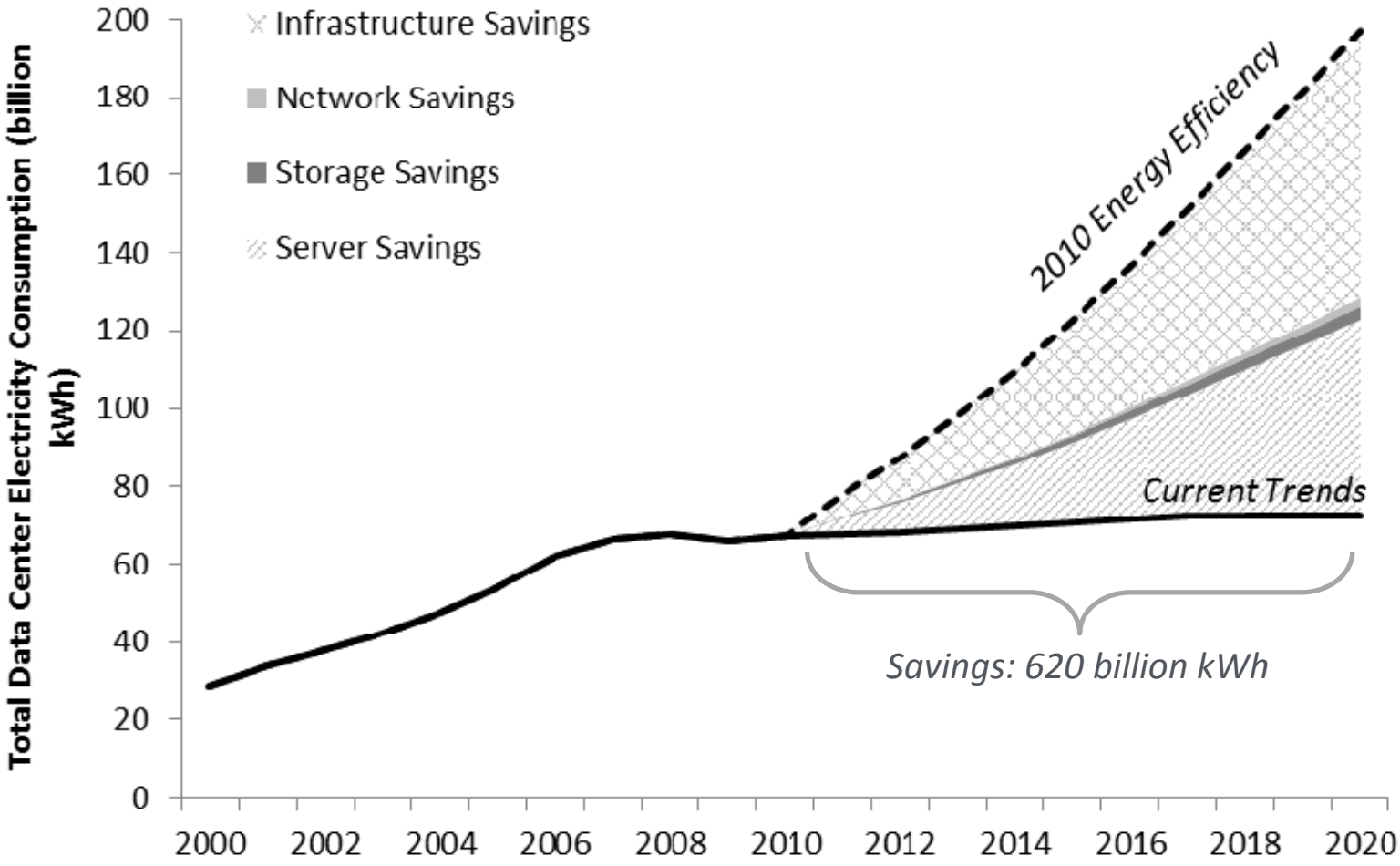


Energy Use Estimates by Data Center Type

- Hyperscale is a growing percentage of data center energy use

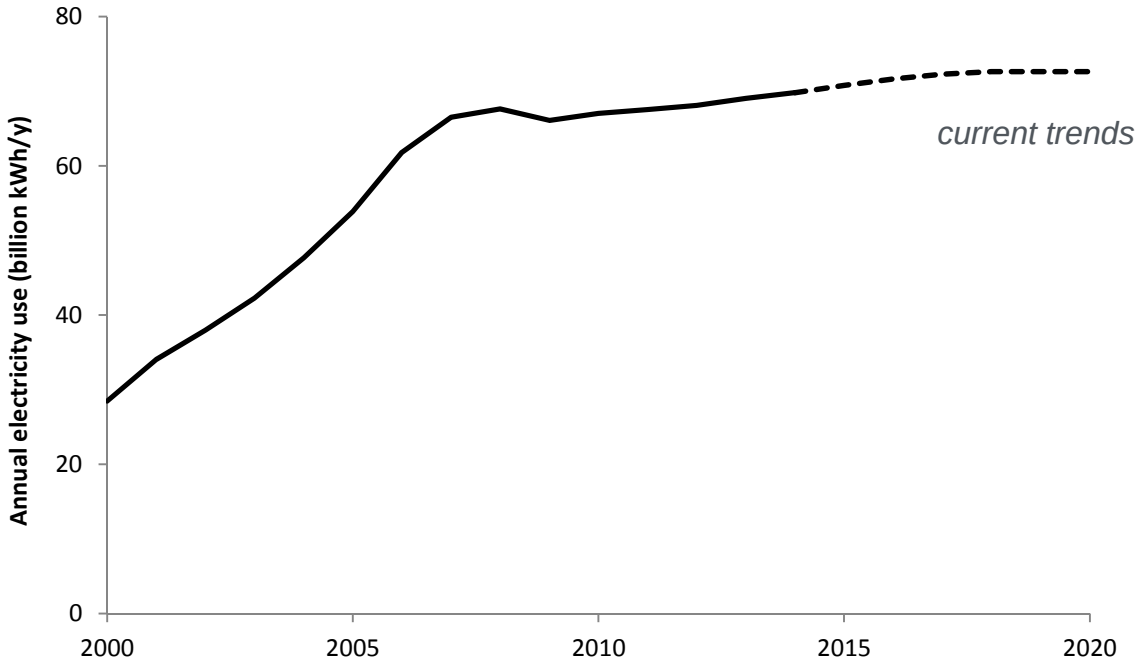


Energy Use Estimates and Counterfactual



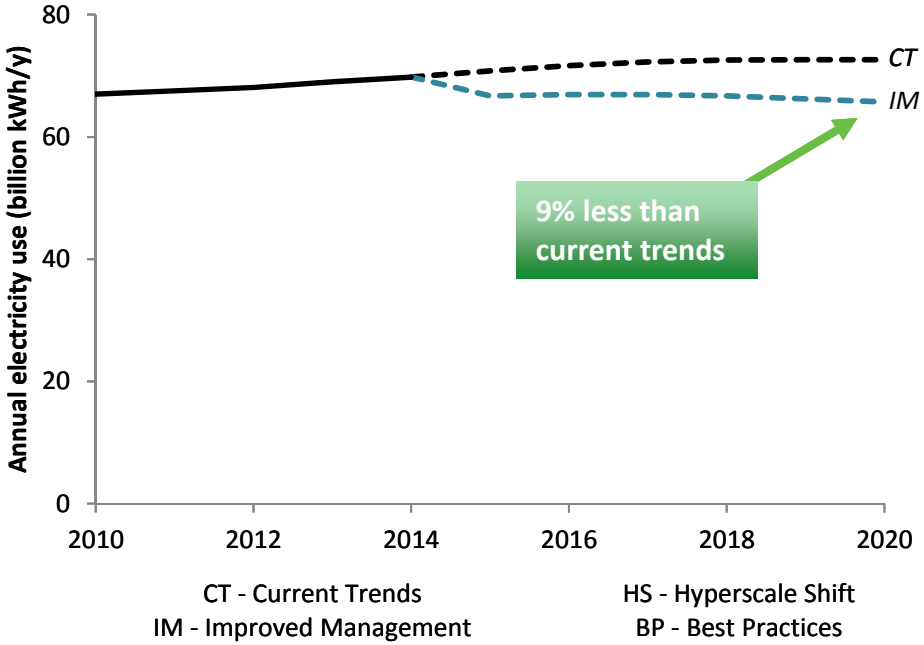
More Savings Available through Efficiency

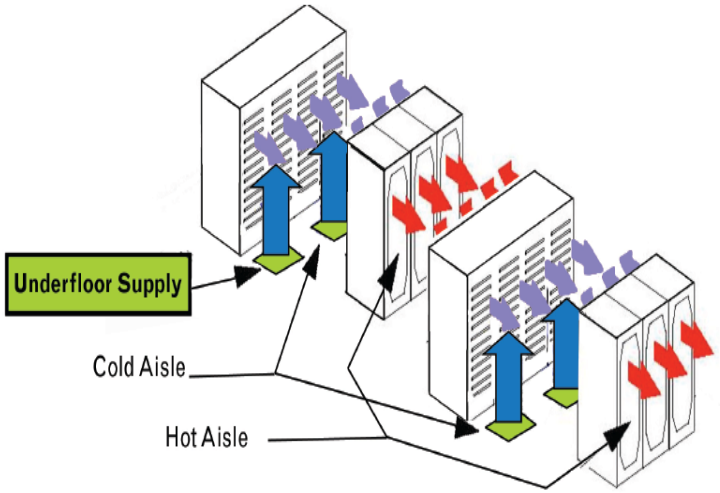
- Stable energy demand while meeting drastic increases in data center services
- Near-term energy demand projected to continue to be constant
- Lots of energy savings still available in data centers



Efficiency Scenarios: Improved Management

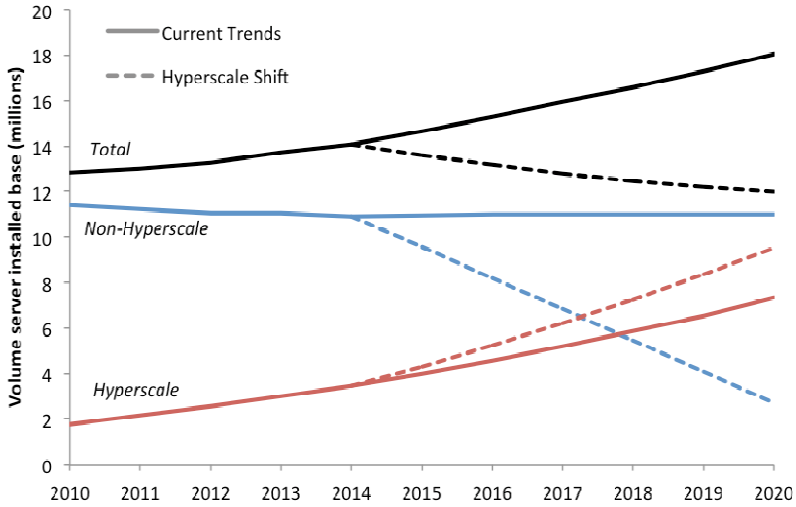
- Remove inactive servers
- Improved PUE through thermal management

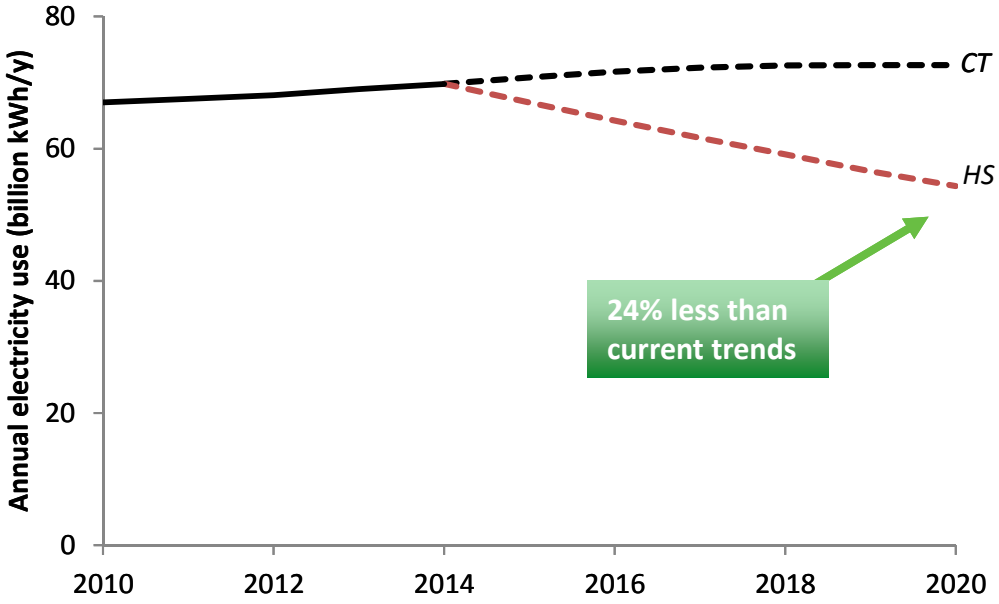




Efficiency Scenarios: Hyperscale Shift

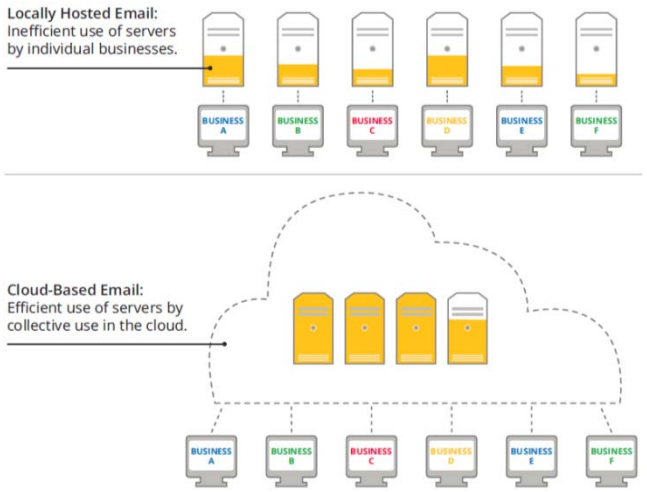
- Aggressive move to the cloud
  - Consolidate of 80% of servers in non-hyperscale data centers into hyperscale by 2020
  - Excludes server provider rooms and closets





CT - Current Trends
IM - Improved Management

HS - Hyperscale Shift
BP - Best Practices



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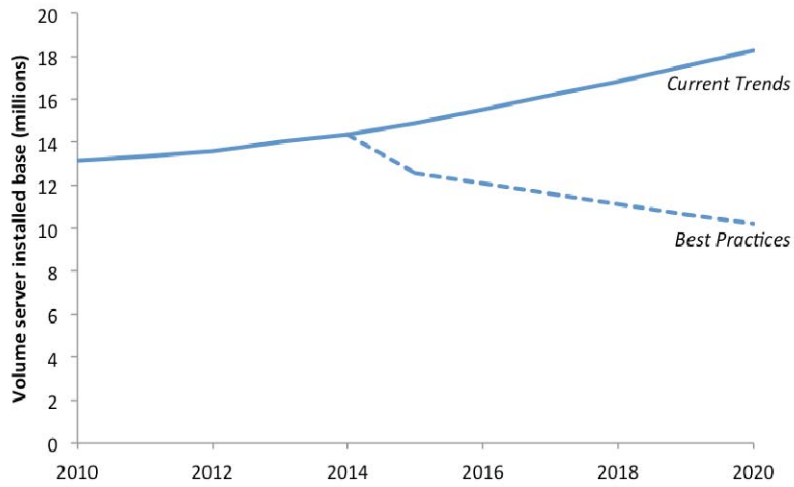
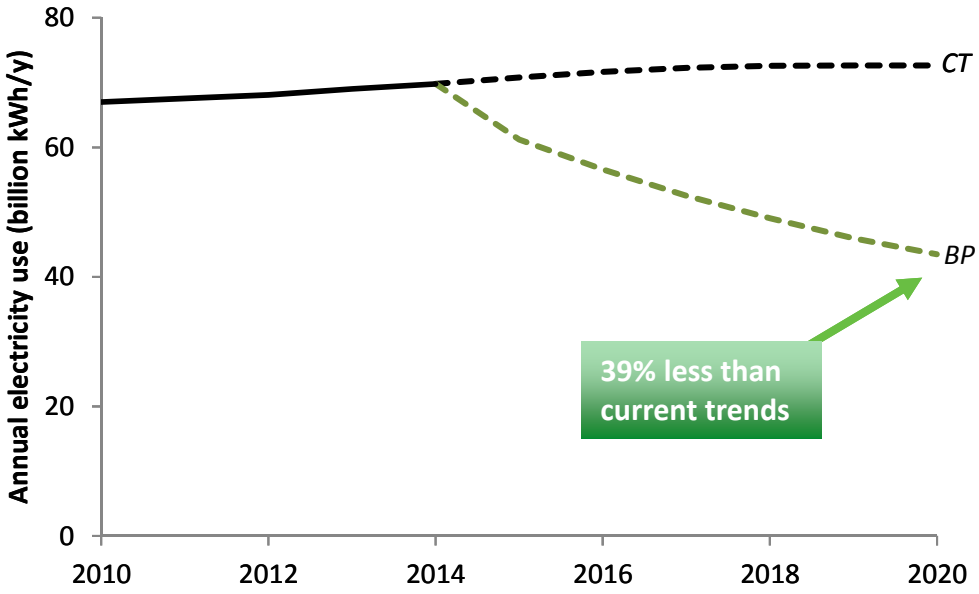
Efficiency Scenarios: Best Practices

Improved Management, plus:

- Improved PUE values
- Greater server/network consolidation
- Improved power scaling
- Reduced storage/network power





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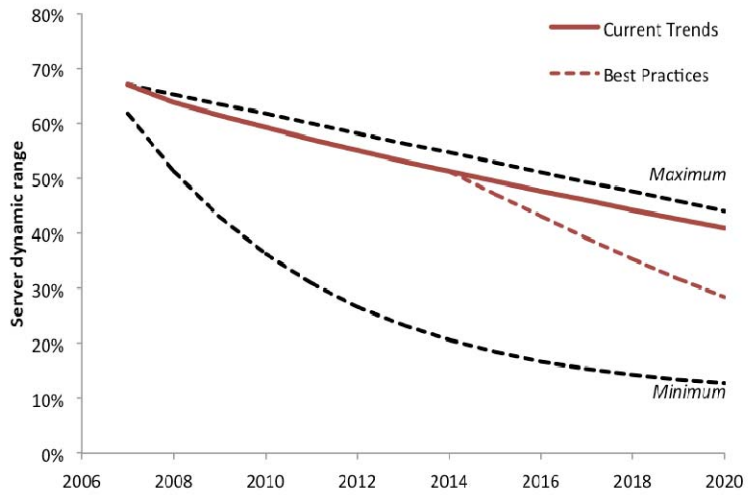

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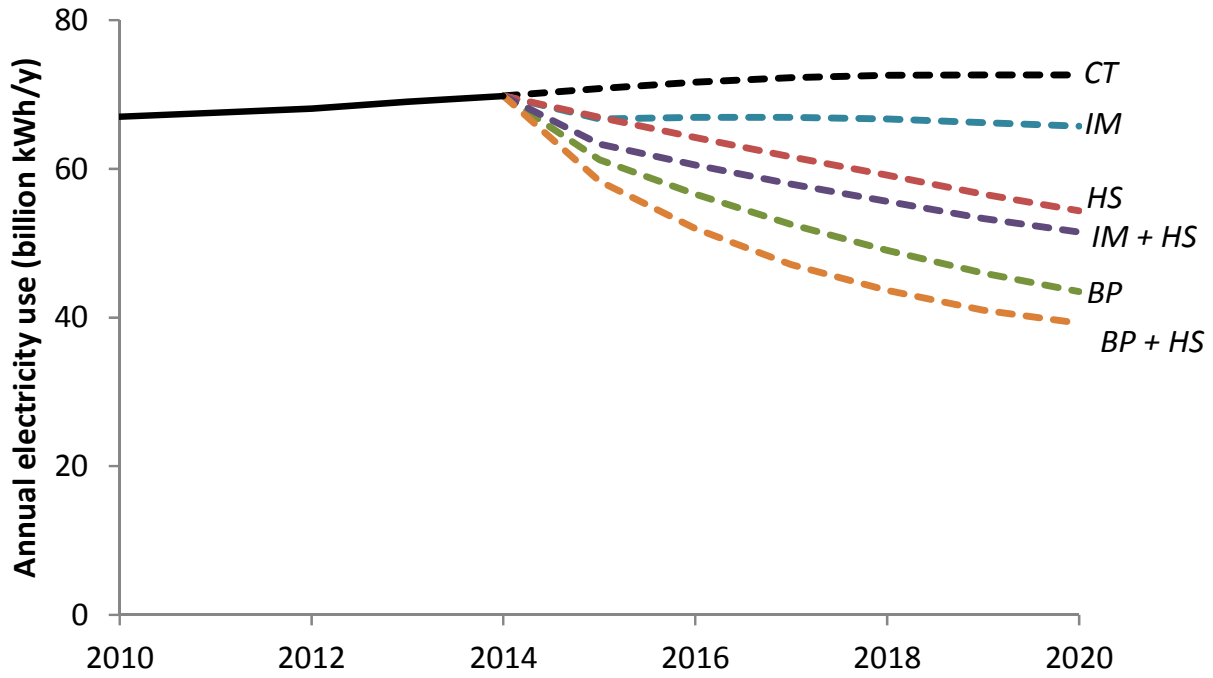
More Savings Available through Efficiency

- Annual saving in 2020 up to 33 billion kWh
- Represents a 45% reduction in electricity demand over current trends



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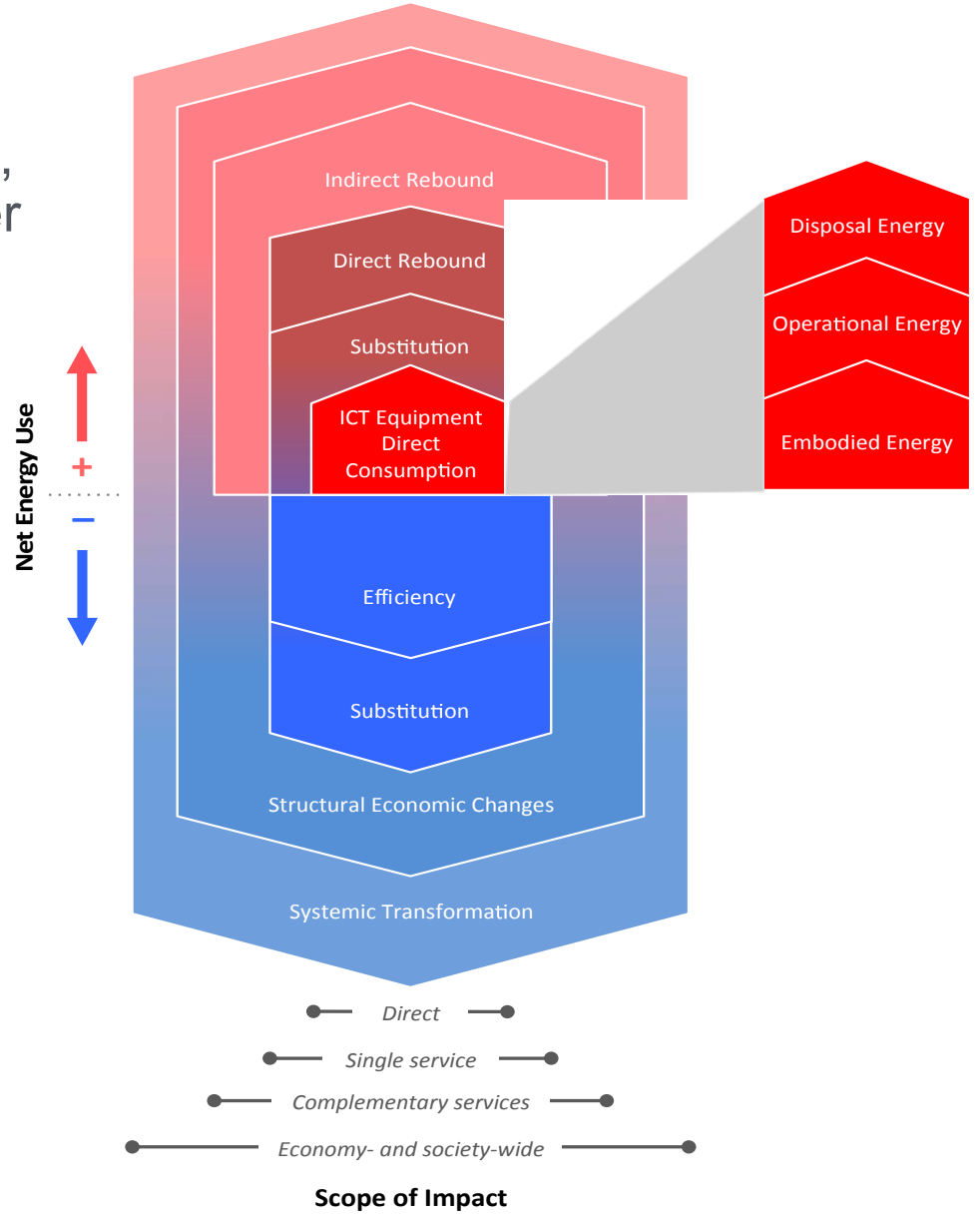
Indirect Impacts

- Indirect impacts are characterized, each type with increasingly greater magnitude than direct impacts
  - All highly uncertain and variable
  - Net impact not clear
- Potentially decrease resource consumption through improved efficiency and substitution
- Other impacts could increase resource consumption or shift practices to more damaging activities



Future Challenges & Opportunities

Data center closet clunkers :

- Promote shift towards cloud and colocation
- Improving/removing remaining closet and other poorly operated smaller data centers

the early days at LBNL…

Changing Landscape:

- Growth of small “edge” network data centers to complement large hyperscale data centers

Beyond 2020:

- Established efficiency measures (consolidation, power scaling, low PUE) to eventually hit upper limit
- Computational/storage demand only increasing

Resources

- Report for download: https://datacenters.lbl.gov/resources/united-states-data-center-energy-usage

- Article on Indirect Data Center Impacts:
  Known unknowns: indirect energy effects of information and communication technology, Environ. Res. Lett. 11 103001
  https://dx.doi.org/10.1088/1748-9326/11/10/103001

- Center of Expertise website: datacenters.lbl.gov
  - Information on best practice technologies and strategies (Technologies)
  - Tools covering areas such as air management and writing an energy assessment report (Tools)
  - Database of resources including reports, guides, case studies (Resources)
  - Need assistance? (Contact Us form)

Questions?

- To be unmuted to ask a question, please go to your meeting controls panel and raise your hand
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- Slides will be available at datacenterworkshop.lbl.gov
- For content-related questions after the webinar, please email Arman: ashehabi@lbl.gov
- Other questions? Please email Elena: Elena.Meehan@ee.doe.gov

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https://fempcentral.energy.gov/Training/EventRegistration/EvaluationForm.aspx