Los Alamos
NATIONAL LABORATORY

EST. 1943

Delivering science and technology
to protect our nation
and promote world stability

National Nuclear Security Administration

Operated by Los Alamos National Security, LLC for the U.S. Department of Energy's NNSA

Energy Efficiency Economics

Obstacles and Opportunities

Dr. Josip Loncaric

Nov. 13th, 2016

Operated by Los Alamos National Security, LLC for the U.S. Department of Energy's NNSA

LA-UR-16-27158

Talk objective: Teach a man to fish

Nov. 13th, 2016

Energy Efficiency Economics

SC16: EE HPC WG Workshop

- **Justifying energy efficiency**
  - Must show benefits
  - Constrained design optimization
- **Obstacles**
  - Schedule, budget, etc.
  - Accounting rules
  - Expanding operating envelope
- **Opportunities**
  - Costs of time and energy
  - More computing within constraints
  - New life for old facilities
- **Global IT limited by energy**
- **Summary**

Justifying Energy Efficiency

Energy efficiency argument must show benefits

- **Saving energy isn't convincing by itself.**
- **Saving time and/or money may be. So can performance improvements.**
- **Example 1:**
  - Liquid cooling may reduce energy use by 25%
  - Great, but will it save money? Can it be ready in time?

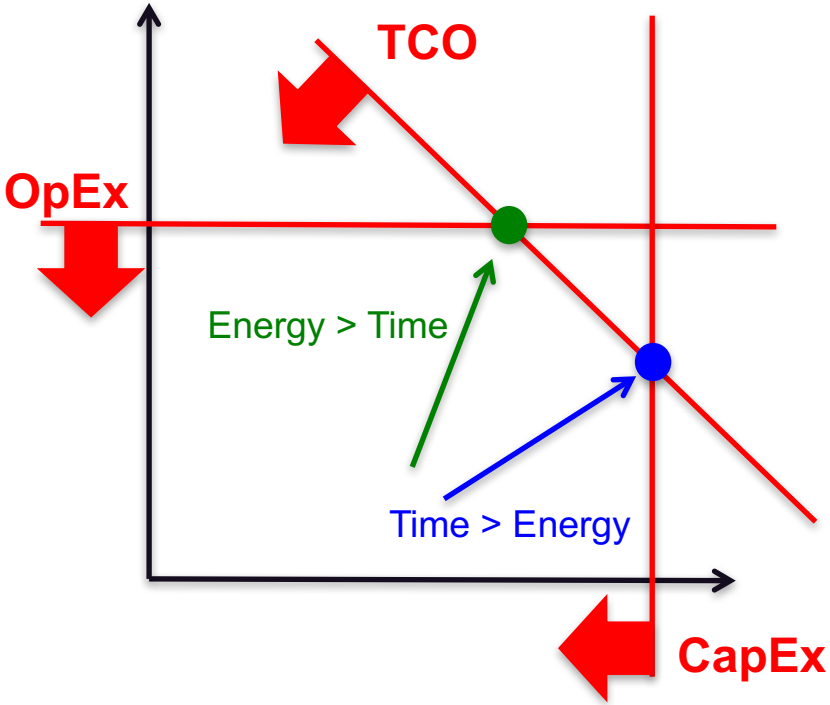
- **Example 2:**
  - CPU race to idle reduces wasted energy
  - Great, but do rapid power transients cause problems elsewhere?

- **Example 3:**
  - Reducing energy use reduces operating costs
  - Great, but it's more valuable to maximize throughput
- **How does one argue for deploying energy efficient technologies?**
  - That's what the rest of this talk is about: *Winning* this argument

Constrained design optimization

- **Constraints are obstacles**
  - Operating expense constraint
  - Capital expense constraint
  - Total cost of ownership constraint
- **Objectives are opportunities**
  - Time more valuable than energy
  - Energy more valuable than time
- **Different designs may result**
- **Full economic view needed**
  - Facilities, platform, energy, time, …

Know your constraints and objectives!



Obstacles

Basics of facilities and platforms

- **Facilities**
  - Long lead time for approvals, design and build
  - Once built, define operating envelope (MW)
  - Must evolve with the computing demand
  - Design and build process to expand capabilities requires years
  - Upgrading power feed could take even more time and money
- **Commodity technology systems**
  - Price/performance optimized, rapid deployment (weeks)
  - Usually fit existing facilities
- **Advanced technology systems**
  - Optimized for capability, push frontiers of computing, complex
  - Long lead time allows for needed facility upgrades

Schedule as an obstacle

- **Insufficient lead time is a constraint on what can be done**
- **Example:**
  - Commodity technology system with energy efficient liquid cooling option
  - Contract to deployment: a couple of months
  - However, the facility preparation for liquid cooling requires plumbing
  - Procurement, design & build to modify the facility: many months
  - Outcome: energy efficient technology doesn't fit schedule, not deployed
- **Suggestion:**
  - Simplify and shorten site preparation for energy efficient platforms
  - Pre-fabricated site preparation kits may help rapid deployments
- **Beware of local regulatory requirements**
  - Longer path may be required by your organization
  - Work to make shorter path acceptable

Budget as an obstacle

- **Site preparation requires money**
- **Example:**
  - Site has air cooling, but preparing for liquid cooling requires too much money
  - Outcome: energy efficient technology doesn't fit budget, not deployed
- **Suggestion:**
  - Seek cost effective site preparation for energy efficient platforms
  - Justify facility upgrades on the basis of capability amortized over time
  - Pre-fabricated site preparation kits may help reduce costs
- **Beware of local regulatory requirements**
  - Costlier path may be required by your organization
  - Work to make reduced cost path acceptable

Accounting as an obstacle

- **Accounting rules force sub-optimal solutions**
  - “Color of money” constraints
- **Example:**
  - Overall budget split into CapEx and OpEx
  - Separate funding streams force separate optimizations
  - Energy efficient option adds to CapEx, reduces OpEx
  - CapEx optimization can’t recover OpEx savings (different color of money)
  - Outcome: energy efficient option not chosen
- **Suggestion:**
  - Request specific top-level guidance that *best value in the TCO sense* is the goal
  - Find accounting mechanism to recover OpEx savings

Economics of energy efficiency as an obstacle

- **Energy efficiency may increase net costs**
- **Example:**
  - Energy efficient option increases platform cost 5% of CapEx
  - Site preparation for energy efficient platform adds another 5% of CapEx
  - Overall extra cost is 10% of CapEx
  - Lifetime OpEx savings are 25% of OpEx
  - However, lifetime OpEx is only 24% of CapEx, so savings are only 6% of CapEx
  - Overall: Energy efficiency increases TCO by 4% of CapEx
  - Outcome: Energy efficient option not chosen
- **Suggestion:**
  - Carefully consider bottom line impacts
  - Analysis should not miss other costs and benefits, such as performance or reliability
  - Be aware of trends, such as OpEx growing in relative importance

Opportunities

Costs of time and energy

- **Combined cost of time and energy as objective**
- **Example:**
  - Time is money: time on the computer, time in the facility, people's time, lost time
  - Energy is money, defined by complex legal language of the energy contract
  - Total cost is the sum of the two
  - Objective: Minimize total cost within schedule, budget, and physical constraints
- **Note:**
  - Time to solution may be strongly constrained by deadlines
- **Suggestion:**
  - Saving energy costs without increasing time to solution is preferable
  - Carefully analyze how your institution values time vs. energy costs

Performance maximization objective

- **HPC is bought for *High Performance* Computing**
- **Example:**
  - In many cases, time is much more valuable than energy
  - Saving energy isn't seen as a worthy objective
  - Maximizing performance is valued
- **However:**
  - Maximizing performance without energy efficiency requires more power & cooling
  - Existing facilities limit power & cooling
  - Provisioning more is expensive: new power feeds, new cooling, new facility, time
- **Suggestion:**
  - Energy efficiency maximizes performance within the existing operating envelope
  - This argument aligns with institutional objectives even if energy is free
  - Motivate energy efficiency by performance improvements within physical constraints
  - This argument can also justify system replacements with new, more efficient ones

Expanding operational envelope

- **Advancing frontiers of computing requires investments**
- **Example:**
  - Advanced technology system requires more power & cooling
  - Liquid cooling is also driven by high power densities
  - Power & cooling facility upgrades may cost >20% of platform
  - Forced by advanced technology requirements
    - Liquid cooling is a *must*
  - Facility investments are amortized over several platforms

- **Beyond upgrades of a facility:**
  - Even larger investments in power feed to the facility and electricity generation
  - Expanding operational envelope further encounters increasing costs
  - Costs eventually limit expansion
  - Energy efficiency improvements deliver more performance without further expansion

New life for old facilities

- **27-year old facility**
- **Existing air cooling**
  - With structural airflow constraints
- **Liquid cooling option is costly**
  - Site preparation cost ~10 % of platform
  - Platform LC option cost ~5%
- **Rationale for choosing LC**
  - *Deliver 250% computing in old facility*
  - Path for future platforms
  - Expectation of more robust performance and improved reliability due to cooler CPUs
- **Bottom line: No choice**
  - Air cooling could not deliver capability

Global IT Limited by Energy

Global IT poised to consume global electricity supply

- **World's information processing demand grows exponentially**
  - HPC is just a small portion
  - Personal devices, networks, data centers, other communications need power
  - Exponential capability growth demands energy
- **Energy efficient technologies are the key**
  - The entire IT industry is strongly driven by this objective
  - Energy efficient packaging (e.g. power delivery, power conversion, etc)
  - Energy efficient controls, at all levels (circuit to data center)
  - Energy efficient cooling (liquid, air)
- **Energy efficiency requires economic justification at every turn**
  - Decisions are made on the basis of bottom line impacts
  - Make your case by identifying specific benefits to your institution

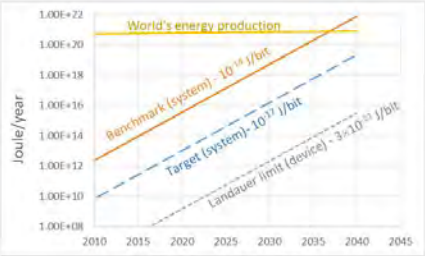


Fig. A8. Total energy of computing.

Rebooting the IT Revolution: A Call to Action, SIA and SRC report, Sep. 2015

Energy efficiency is the key to more performance

- Energy efficiency isn't an end in itself
- Energy efficiency must be justified economically
- In HPC, saving time is usually more valuable than saving energy
- However, operating envelope constraints are critical
- Energy efficiency can be economically superior to expansion of the operating envelope
- This observation applies to individual institutions as well as globally

Maximizing performance under constraints requires energy efficiency