Capping the Brown Energy Consumption of Internet Services at Low Cost

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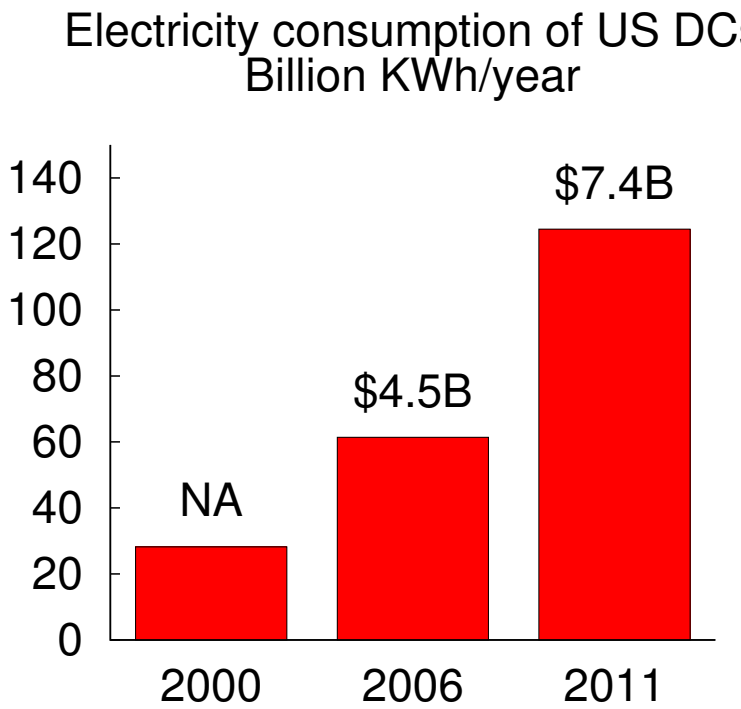
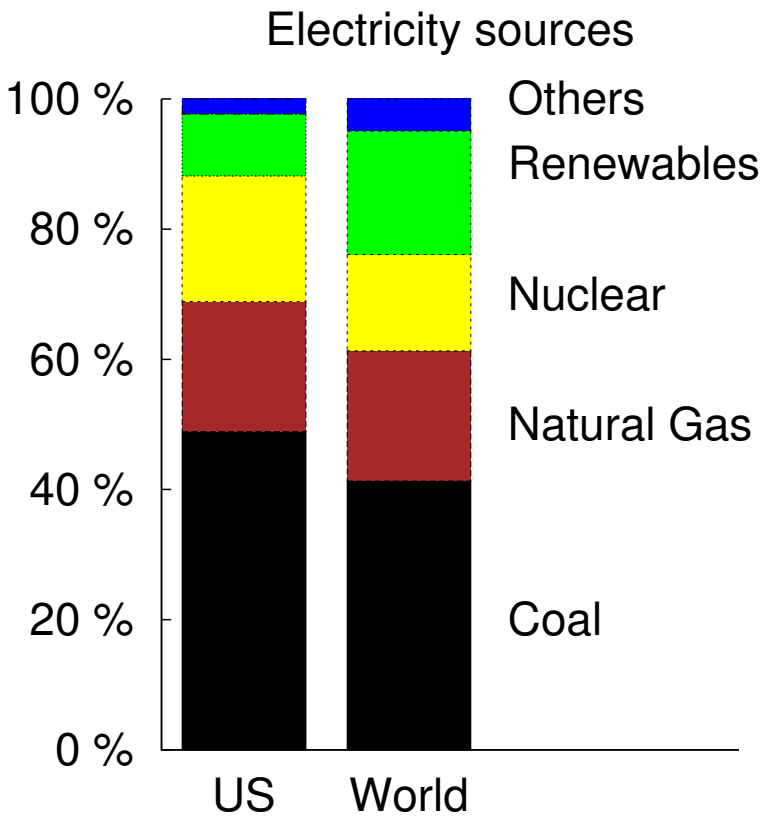
Energy Consumption of Data Centers

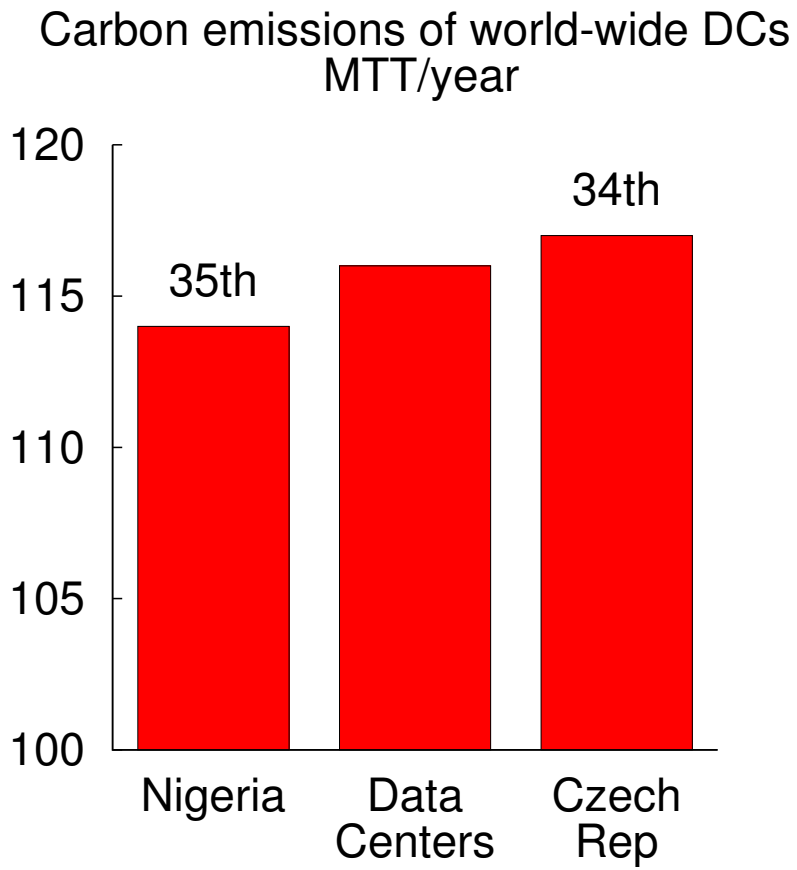


- Equals consumption of transportation manufacturing industry in 2006
- Est. 124.5 BKWh for 2011

Source: EPA 2006

Environmental Costs





Sources: DOE and Mankoff08

Capping Brown Energy Consumption

- Improving efficiency does not promote green energy or guarantee limits on brown energy
- Trend: Cap the brown energy consumption of large electricity consumers (data centers)
- Capping schemes
  - Cap-and-trade: purchase carbon offsets
  - Cap-and-pay: pay higher brown energy price
  - Cap-as-target: pay more for neutrality

Capping Brown Energy Consumption (cont.)

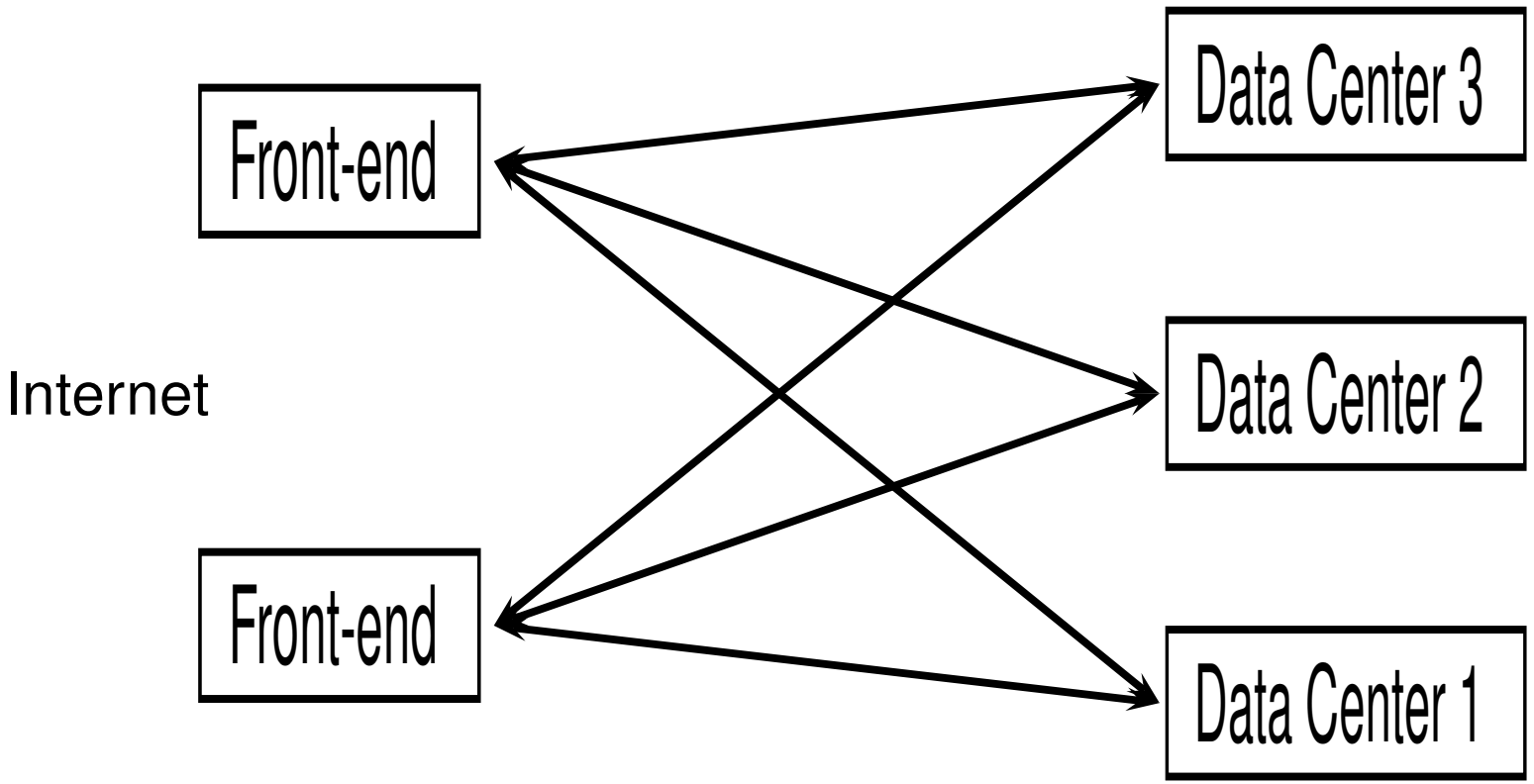
- Real example: UK CRC Energy Efficiency Scheme
  - Mandatory cap-and-trade scheme starting in April 2010
  - Organizations consuming $\geq$ 6 GWh/year
  - Affecting 20,000 organizations
- Cap brown energy without degrading performance or excessively increasing costs and overheads?
- Our current focus: Multi-DC Internet services

Characteristics of Internet Services

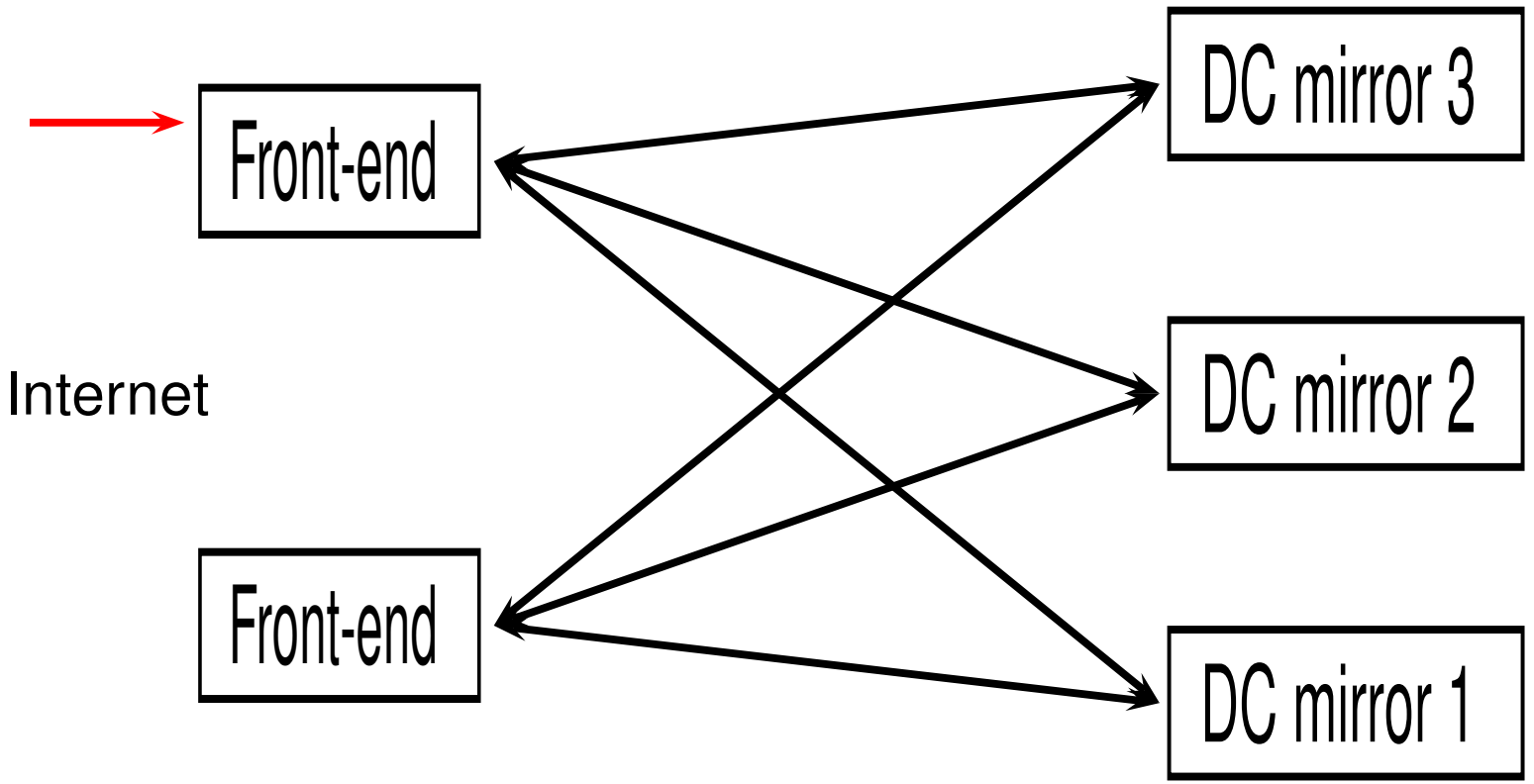
Company	Servers	Electricity	Cost	CO_2(Tons)
eBay	16K	0.6×10^5 MWh	\$3.7M	0.43×10^7
Akamai	40K	1.7×10^5 MWh	\$10M	1.2×10^7
Rackspace	50K	2×10^5 MWh	\$12M	1.4×10^7
Microsoft	>200K	$> 6 \times 10^5$ MWh	>\$36M	4.3×10^7
Google	>500K	$> 6.3 \times 10^5$ MWh	>\$38M	4.5×10^7

Source: Qureshi et al., SIGCOMM 09

Multi-DC Internet Services

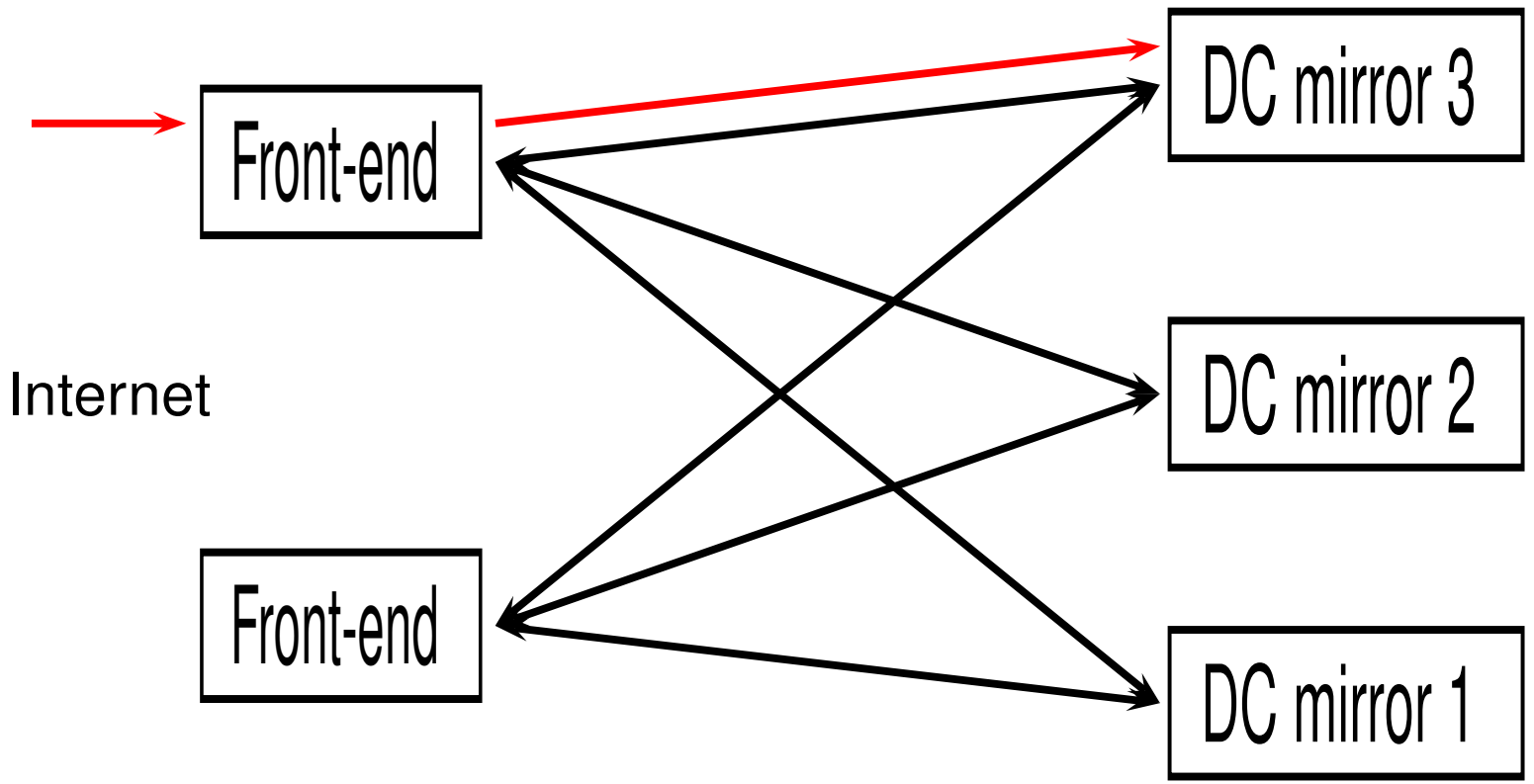


Across-DC Request Distribution



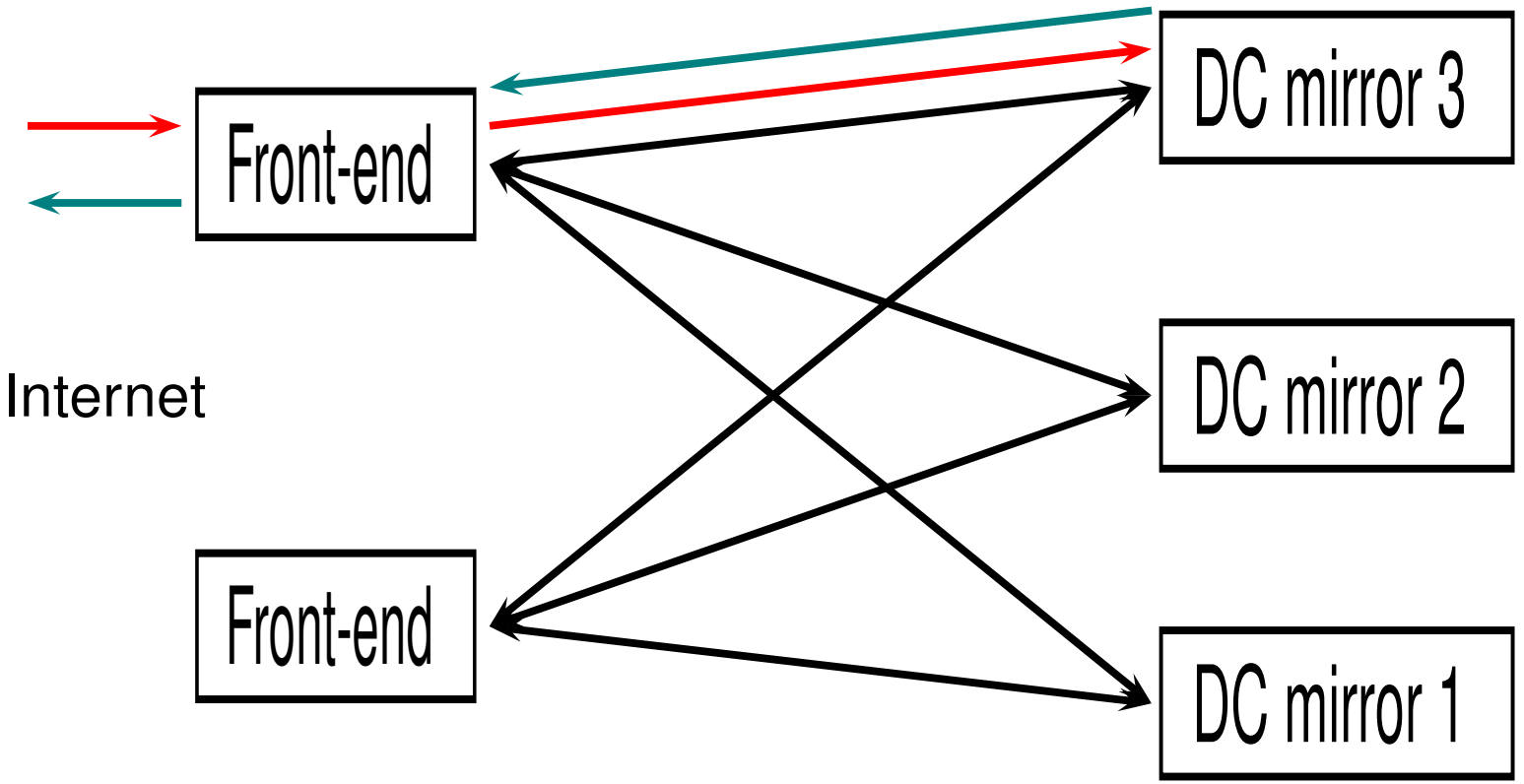
Typically, a request can be served by 2-3 mirror DCs

Across-DC Request Distribution



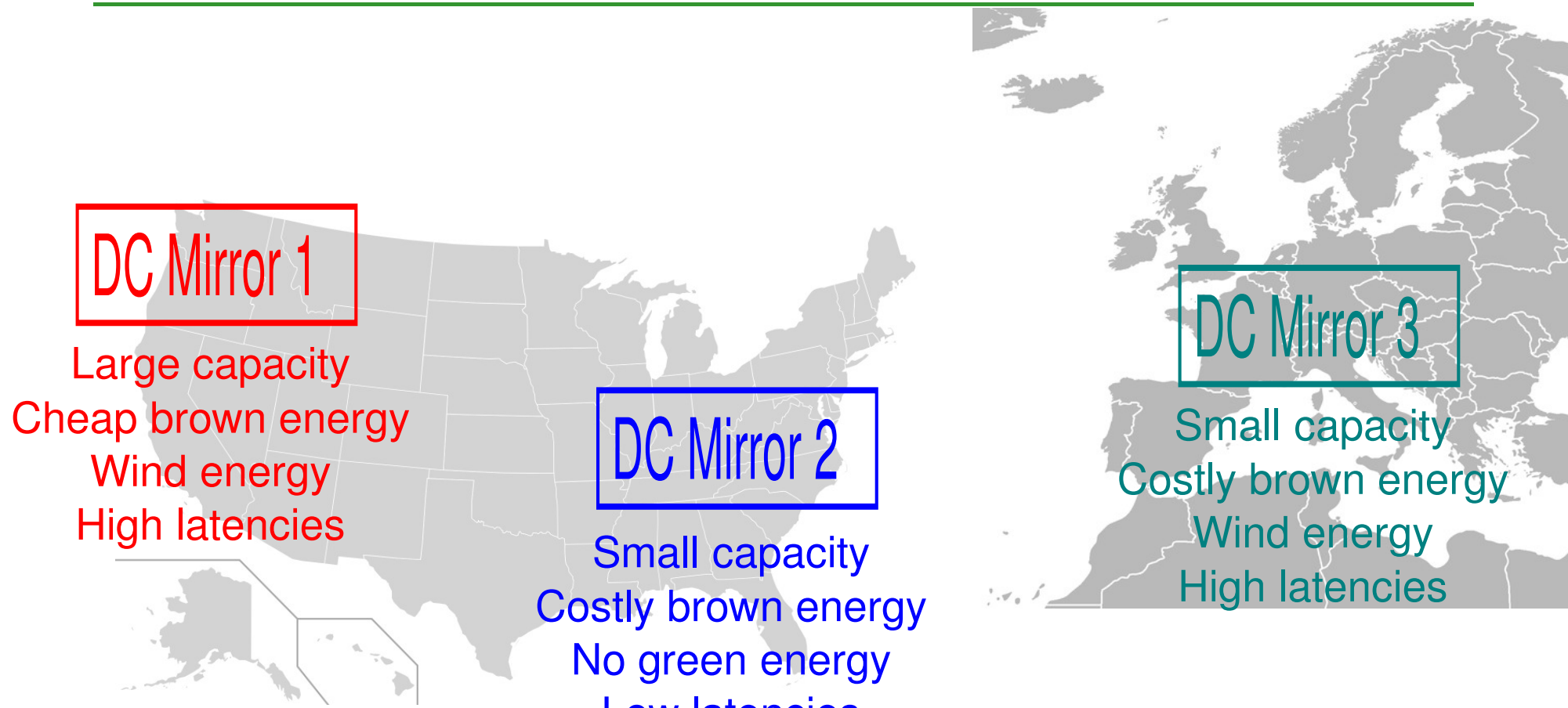
Request distribution policy determines the DC to use

Across-DC Request Distribution



Policy must account for potential increase in response time (SLA)

Geographical Distribution of Data Centers



DC Mirror 1

Large capacity
Cheap brown energy
Wind energy
High latencies

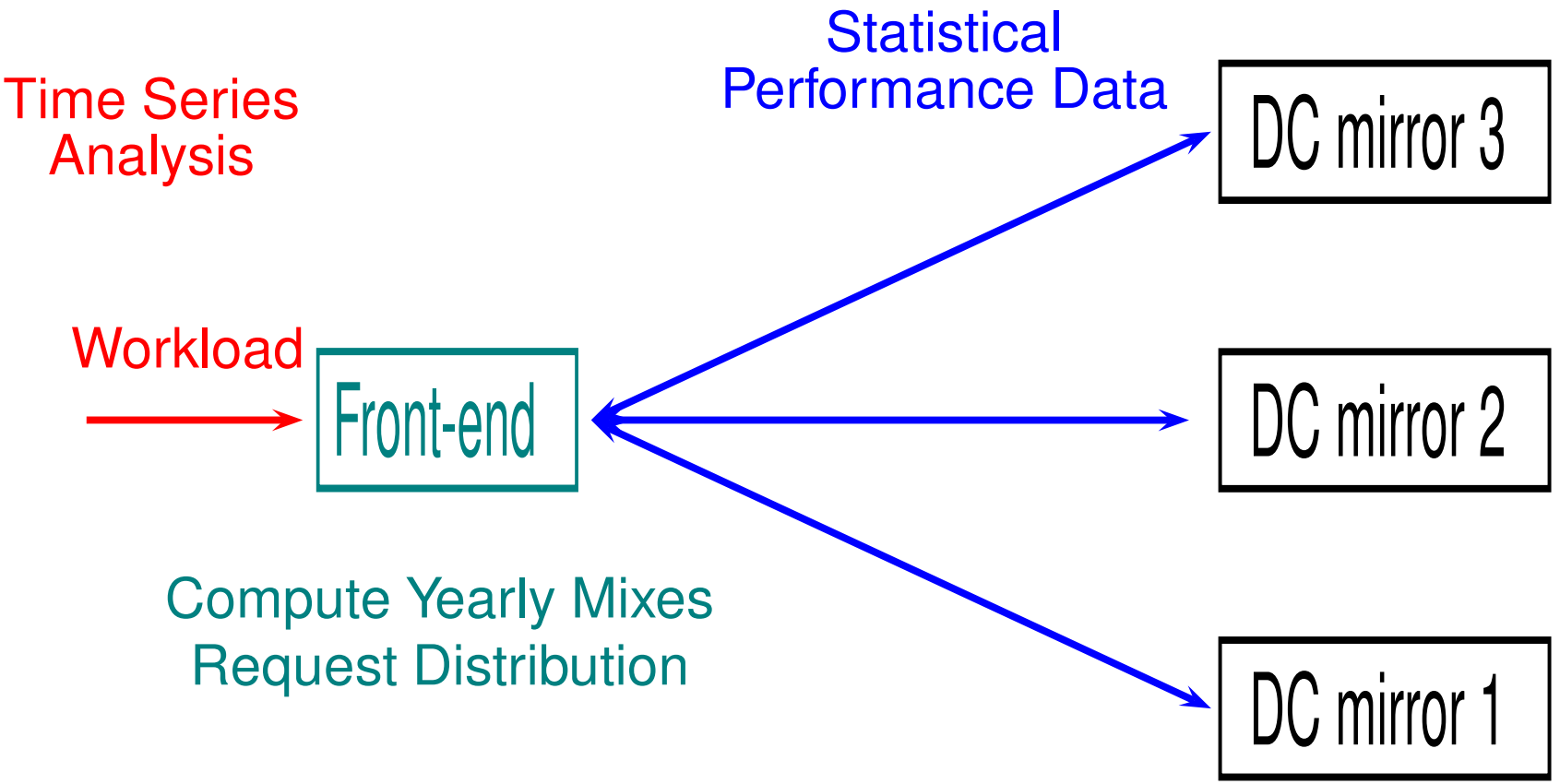
DC Mirror 2

Small capacity
Costly brown energy
No green energy
Low latencies

DC Mirror 3

Small capacity
Costly brown energy
Wind energy
High latencies

Our Work



Minimize cost while satisfying SLA

Cap-and-Trade Distribution Policy

- Goal: Compute f_is that minimize the overall energy cost
- Costs:
  - Base energy + dynamic per-request energy
  - On/off-peak electricity pricing
  - Brown vs. green electricity pricing
  - Purchase offsets if brown cap exhausted
- Constraints:
  - DCs must not be overloaded
  - SLA must not be violated

Approach: Optimization

Optimization-Based Distribution

- Formulate an optimization problem
- Compute power mixes for a year
- Periodically compute distribution fractions
- Use simulated annealing (SA): Week-long load predictions,

  4-hour epochs

Approach: Heuristics

Heuristic-Based Distributions

- Simpler approach
- Forward client requests greedily based on cost and performance
- Cost-aware heuristic (CA): every hour; best cost-perf ratio from well-performing DCs first; later, lowest price
- Cost-unaware heuristic (CU): best performing DCs

Common

- Power mixes computed with SA
- Communicate with DCs for server turn on/off

Evaluation Setup

- DCs: Washington, New Jersey, Switzerland
- Front-end: New Jersey
- Year-long trace of a commercial service
  - Load prediction using ARIMA within 10%
- Real network latencies, brown & green energy prices (on/off-peak), carbon market prices
- Max 30% green energy; Cap: 75% of dynamic energy (enforced per year); SLA: 90% $\leq$ 500ms (per week)

Evaluation Methodology

Methods:

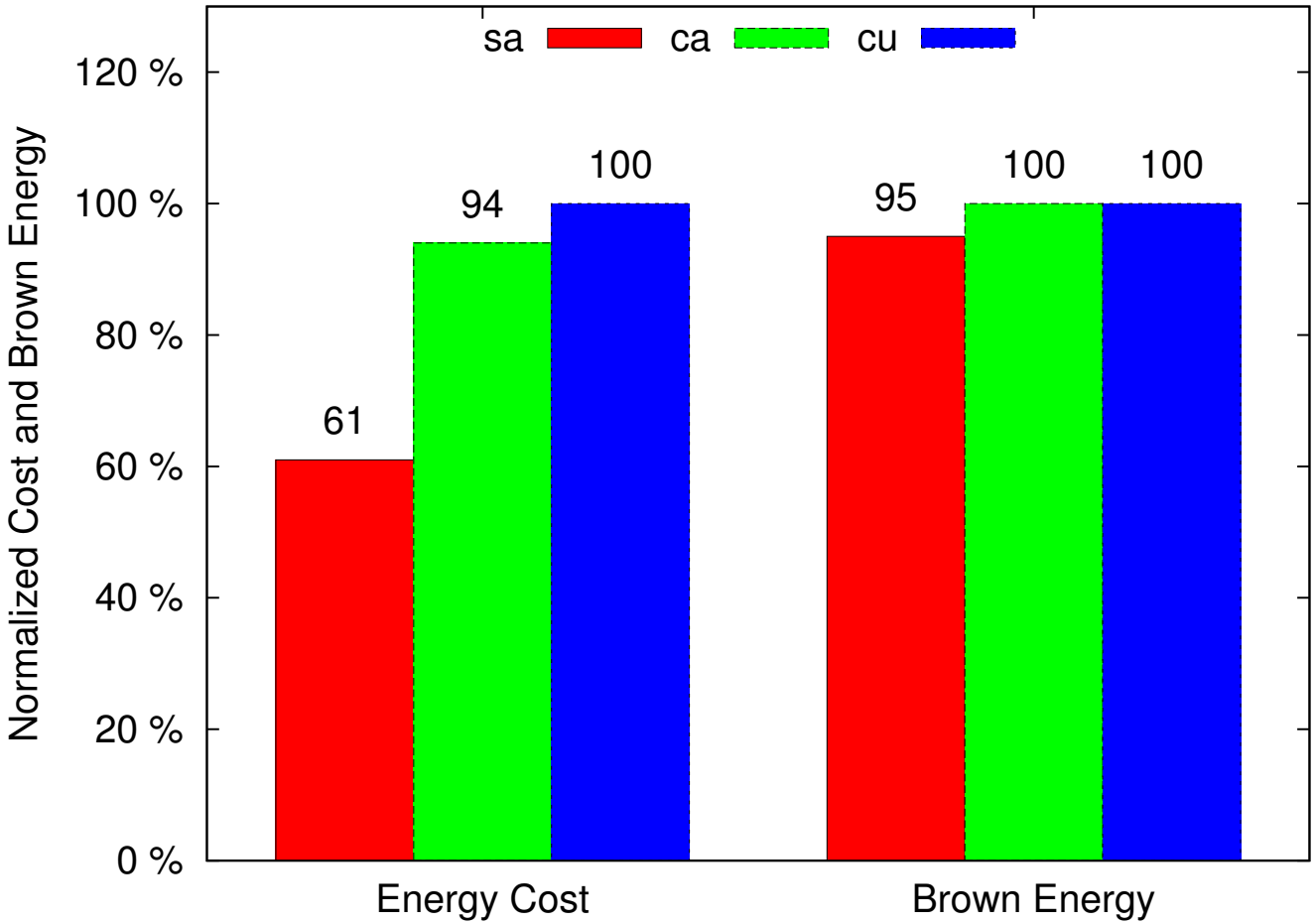
- Simulations
- Real system to validate simulations

SLAs are always satisfied

Real experiments

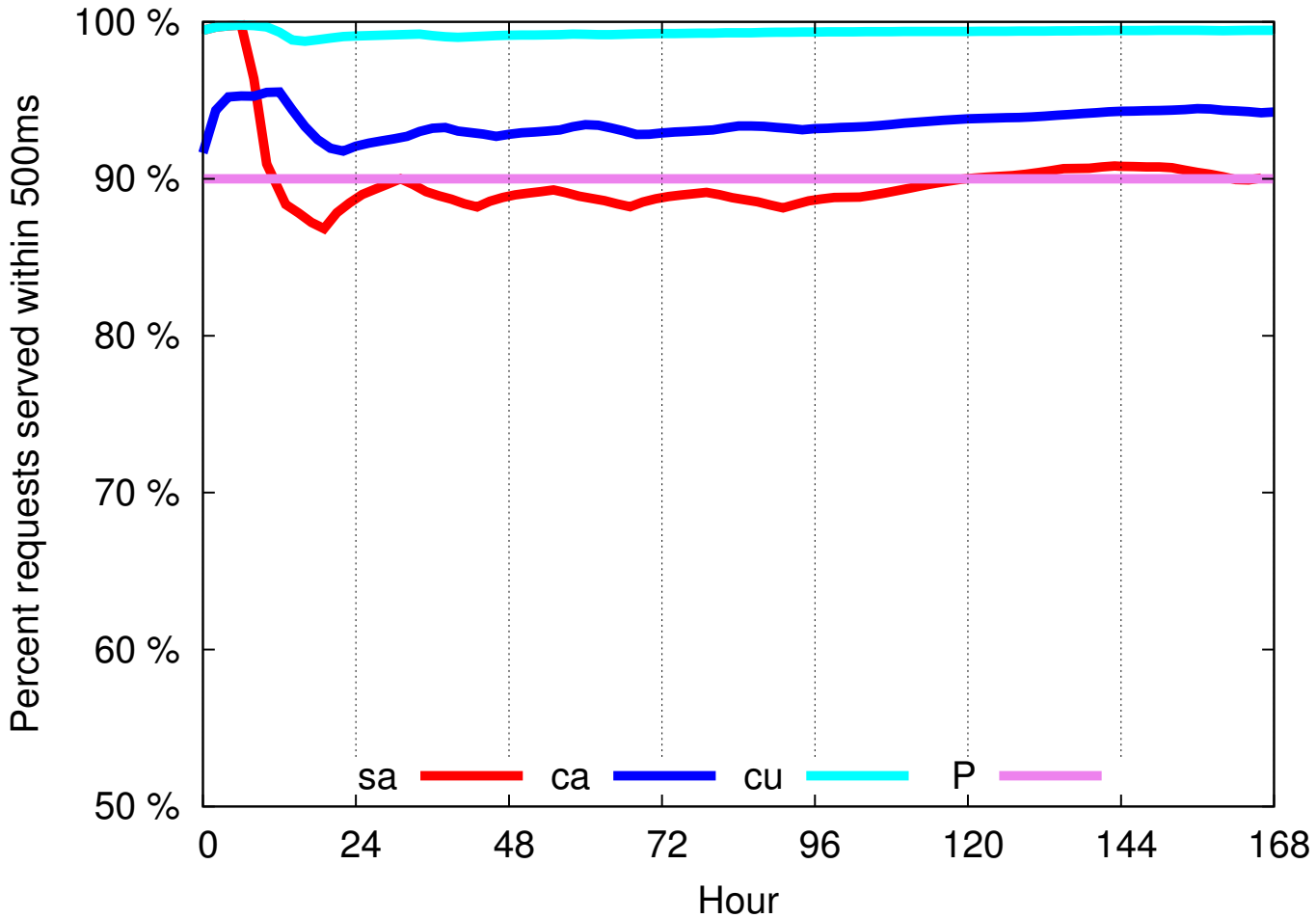
- Based on HAProxy, added 3K lines
- Ran for 40 hours to validate
- **Results within 6% of simulations**

Optimization Beats Heuristics



SA achieves 39% cost savings
CA lowers costs only slightly

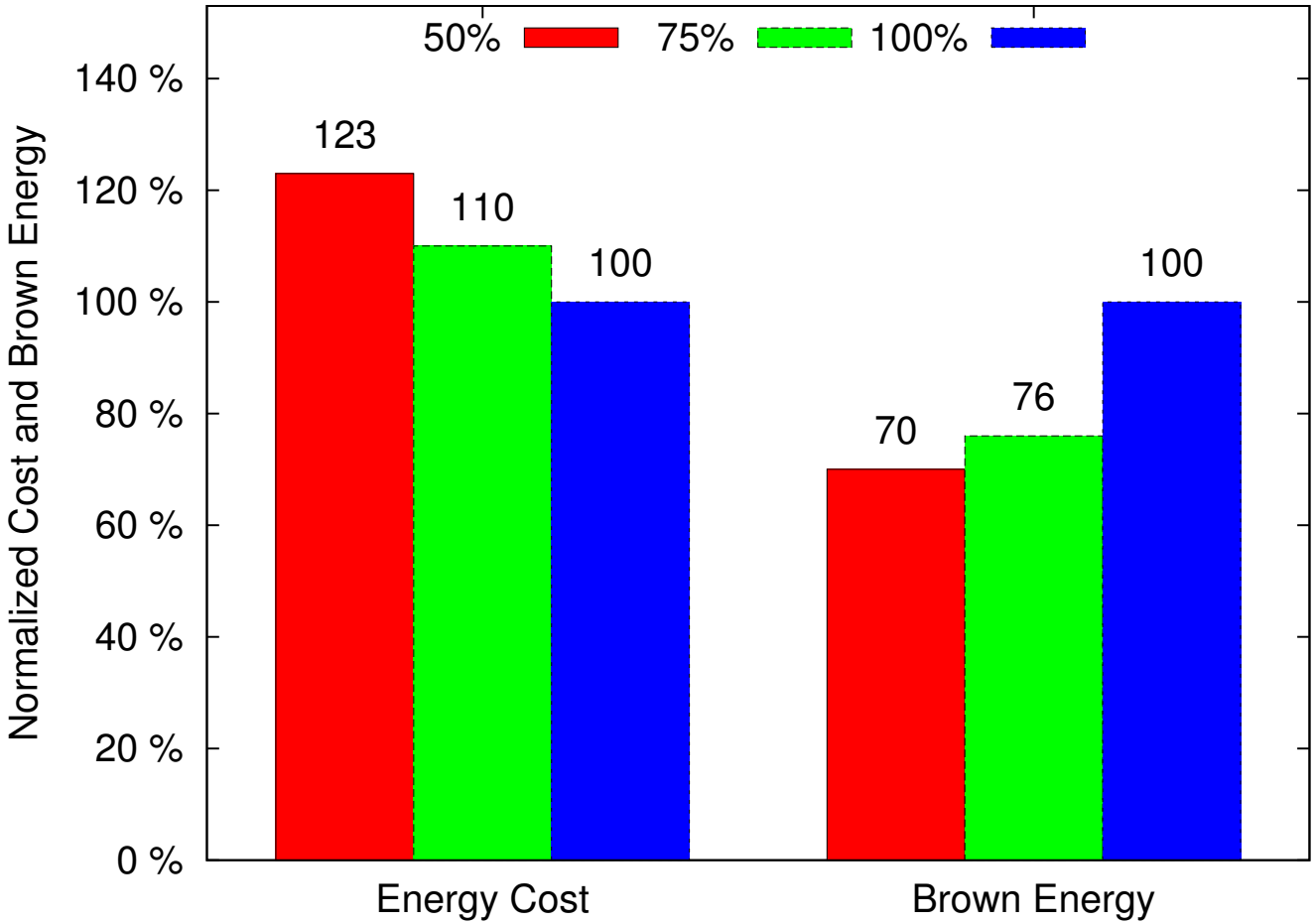
Meeting SLA



SLA: 90% $\leq$ 500ms (per week)

SLAs are satisfied; SA takes advantage of cheap energy

Comparing Caps



75% cap lowers brown energy
by 24% for a 10% cost increase

Conclusion

- Proposed request distribution framework for multi-data-center Internet services to deal with brown energy caps
- Proposed optimization and heuristic techniques for managing energy and cost
- Approach is effective at capping brown energy at low cost
- Optimization behaves better than heuristics
- Given expected brown energy caps, framework and policy should be useful in practice