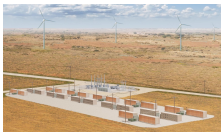
Idea
Uchicago
2015

Reality
McAdoo
2020



Green HPC Practice: Zero-carbon Cloud (Shifting) and Extended Lifetime

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May 20, 2021

Rocky Mountain Advanced Computing Conference

http://zccloud.cs.uchicago.edu/

THE UNIVERSITY OF CHICAGO

Argonne NATIONAL LABORATORY

CERES Center for Unstoppable Computing

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For most of you, the power at your site is growing, perhaps fast!

- This is a problem!
- Growing power density per rack
- Growing square footage at many sites
- Exploding use of AI (and proliferation of 300W GPUs)

⇒What is to be done?

⇒How can we reduce the environmental impact of computing?

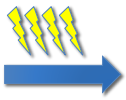
2

How to Reduce your Power (Scope 2) Carbon Emissions

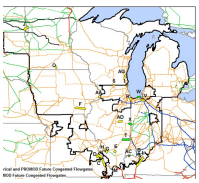
- Deploy renewables (low carbon power) Too HARD!
- Using renewable power from grid, via RECs Financial
- How to REALLY use renewable energy – help the grid to absorb and increase it…
- Key: the grid is going through rapid, extraordinary change

3

What is Stranded Power?



Offer of Power



Power Market, Grid+Load

No! (curtailment)

Pay me! (negative price)

- No! => Curtailment, power is wasted
- Pay me! => negative pricing, generator pays grid

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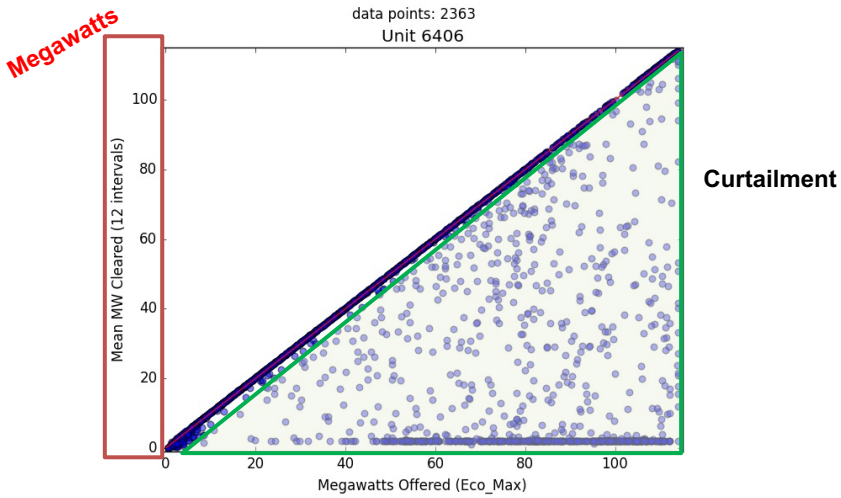
Example: Generator Site – Stranded Power



- EcoMax (potential) vs Delivered [2015: Jan-April], 5 minute intervals

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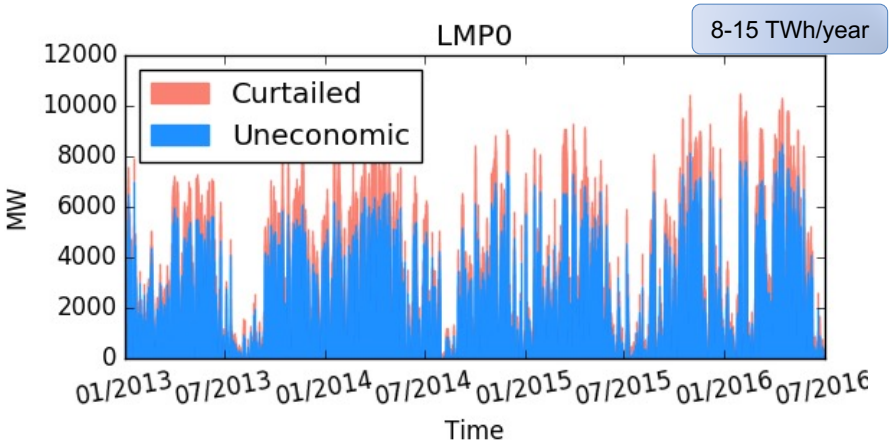
MISO Curtailed and Negative-priced Power



Chien, Yang, Zhang, Characterizing Curtailed and Uneconomic Renewable Power in the Mid-continent Independent System Operator, AIMS Energy, 2018, 6(2): 376-401.

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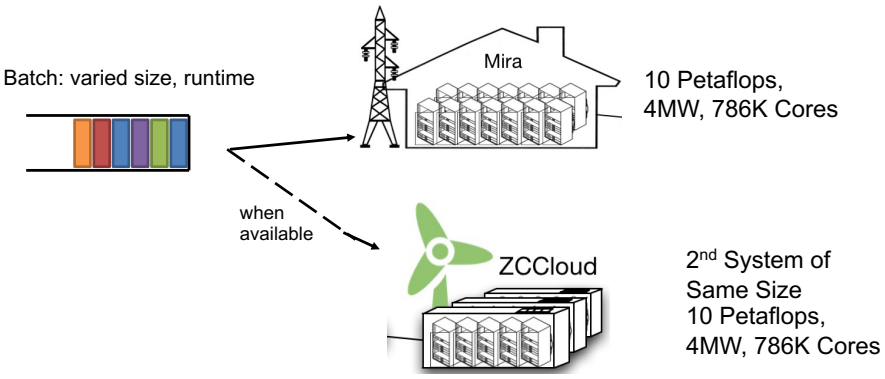
Exploiting Excess power for HPC



- Trace: 1-year workload from Argonne LCF
- Compare – Performance (turnaround time), Total-cost of Ownership

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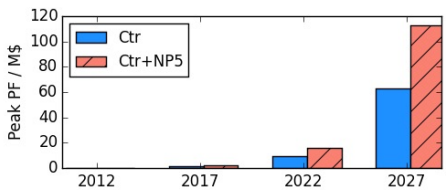
Research Results

- Hybrid system User Turnaround Time is statistically identical! (good service)

Yang and Chien, *ZCCloud: Exploring Wasted Green Power for High-Performance Computing*, IPDPS, April 2016.

- Total Cost of Ownership is competitive in many regions today (depends on power cost)
- Approach enables larger computing facilities (capability) in the future!



Peak is 80% higher by 2027!
Throughput 45% higher.

Yang and Chien, *Scaling Supercomputing with Stranded Power: Costs and Capabilities*, IEEE TPDS 2018.

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But…

- That would require placing your equipment remote…
  - At a wind farm…
  - Or at a "Green Colo"
  - => we have shown you can save BIG on TCO by doing this
  - => and emit a lot less carbon!
  - Or you could…

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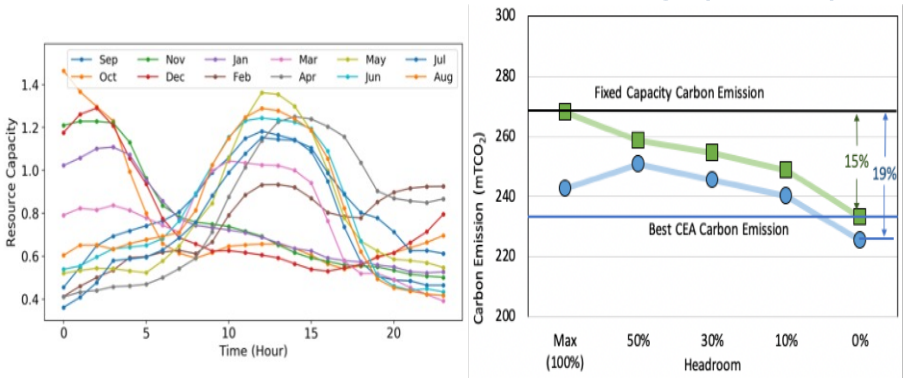
1-site Example: Time Shifting (1 DC)



- Exploit diurnal load and power structure; Constant-carbon increases capacity (German Power Grid)… variation is increasing
- Fixed capacity, CEA reduce emissions by 15%
- Increased scheduling efficiency, Co-optimization enables 19% emission reduction

Zhang and Chien, *Using Carbon-awareness to Reduce the Cloud's Climate Impact*, 2020.

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How to Reduce your Embedded (Scope 3) Carbon Emissions, and your E-Waste

- Some publications suggest that Scope 3 emissions can be comparable to Scope 2
  - Embodied Carbon from Manufacturing Chain
- E-waste is a problem in general

M. Dietrich and A. Chien, Options for Extending the Life of Scientific Computing Equipment, Uchicago TechReport, 2020-08, October, 2020.

- http://zcc-lifetime.cs.uchicago.edu/

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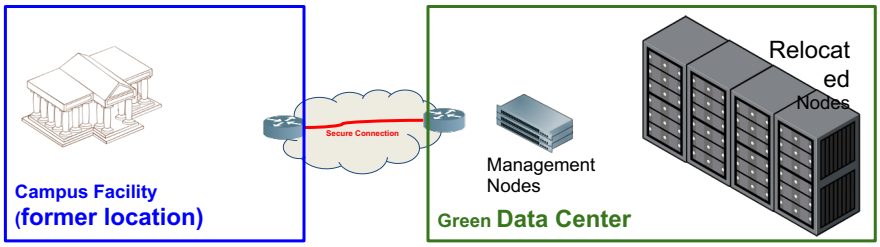
Extended Life (EL) Options in Green Data Centers



- Carbon-emissions free
- Low-cost or bartered hosting

	Green Colocation Facility	Green Computing Service
Reliable Power	**Reliable Green Colocation (RGC)** (e.g. >99.98% availability) Structure: *Pay for colocation*	*NA. Not a new service -- reliable computing services are commercially available.*
Intermittent Power	**Intermittent Green Colocation (IGC1)** (e.g. >90%, 5-minute warning) Structure: *Pay for available hours*	**Intermittent Green Computing (IGC3)** Structure: *Barter computing cycles for hosting*

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Extended Life Options Can Reduce Costs by 36-90%

- We worked with commercial vendors to document three "extended lifetime" (EL) commercial models for scientific computing equipment that are available today.
- A case study shows that extended lifetime options can achieve 36-90% superior cost efficiencies compared purchasing and deploying new equipment.

Case Study Benefits	**Base**	**RGC**	**IGC1**	**IGC3**
3-year savings compared to Baseline	$0	$193,640	$355,036	$688,720
Savings Relocated vs. New	**0%**	**36%**	**53%**	**90%**
Cost / compute in units ($/kSUs)	**$22.91**	**$14.73**	**$10.68**	**$2.31**
Cost/Compute Relative to New Equipment	**n.a.**	**64%**	**47%**	**10%**

Dramatic cost/unit compute efficiencies!

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Industry Activities (ongoing)

- itRenew (https://www.itrenew.com/)

- Buys Equipment and Sells Remanufactured (in x00,000 units), significant discounts
- White paper claims:
  - Reduce TCO by 24-31%
  - Reduce Lifetime Carbon emissions (scope 2 and 3) by 31%
  - Reduction in E-waste (estimated at 50%?)

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Industry Activities

- Circular Electronics Consortium (https://cep2030.org/, 3/25/2021)

accenture CISCO CLOSING THE LOOP DELL Technologies
GLENCORE Google KPMG LANXESS Microsoft
SECURITY MATTERS SIMS LIFECYCLE SERVICES vodafone

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Summary

- Your computing power is growing, and thus so are its carbon-emissions
  - Scope 2 (Power): Time Shifting, and Space Shifting (ideally to stranded power, reach true zero carbon)
  - http://zccloud.cs.uchicago.edu/
  - Scope 3 (embedded): Extend the Lifetime and Shift Older equipment to zero-carbon facilities (reducing space and power cost) "Don't turn it off, move it to a green space!"
  - http://zcc-lifetime.cs.uchicago.edu/

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Zero-carbon Cloud Contributors

- UChicago: (Students) Fan Yang, Chaojie Zhang, Hai Nguyen; (Faculty) John Birge – Booth
- Argonne: Kibaek Kim, Victor Zavala
- UW Madison (Faculty): Victor Zavala, Line Roald, Bernie Lesiutre
- UCSB: (Faculty) Rich Wolski
- California ISO: Mark Rothleder, Shucheng Liu
- ERCOT: Kenan Ogelman

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Zero-Carbon Cloud Papers, I (http://zccloud.cs.uchicago.edu)

- Characterization of Growing ”Stranded power”, MISO, CAISO, ERCOT
  - L. Lin and Andrew A Chien, Evaluating Coupling Models for Datacenters and Power Grids, submitted for publication.
  - L. Lin and Andrew A Chien, Characterizing Stranded Power in the ERCOT in Years 2012-2019: A Preliminary Report, UChicago CS Tech Report, August 4, 2020.
  - L. Lin and Andrew A Chien, Automated Classification of Power Plants by Generation Type, ACM e-Energy '20, June 22-26, 2020
  - A. Chien, F. Yang, and C. Zhang, Characterizing Curtailed and Uneconomic Renewable Power in the Mid-continent Independent System Operator, AIMS Energy, 2018, 6(2).
  - Andrew A Chien, Characterizing Opportunity Power in the California Independent System Operator (CAISO) in Yrs 2015-17, Energy & Earth Science, 11/2020, UchicagoTR, 9/2018.

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Zero-Carbon Cloud Papers, II (http://zccloud.cs.uchicago.edu)

- Scientific & Cloud Computing, Novel Cloud Resource Abstractions
  - Chaojie Zhang and Andrew A Chien, "Scheduling Challenges for Variable Capacity Resources", Workshop on Job Scheduling for Parallel Processing", July 2021
  - Chaojie Zhang and Andrew A. Chien, Using Carbon-awareness to Reduce the Cloud's Environmental Impact, Tech report (in submission).
  - Fan Yang and Andrew A. Chien, ZCCloud: Exploring Wasted Green Power for High-Performance Computing, (IPDPS), May 2016.
  - (Best Paper) Hai Nguyen, C. Zhang, Z. Xiao, and Andrew A. Chien, Real-time Serverless: Enabling Application Performance Guarantees, Workshop on Serverless Computing (WoSC'19), Dec 2019.
  - Chaojie Zhang, Varun Gupta, and Andrew A. Chien, Information Models: Creating and Preserving Value in Volatile Cloud Resources, in the IEEE International Conference on Cloud Engineering (IC2E), June 2019.
  - Andrew A. Chien, Rich Wolski, Fan Yang, Zero-Carbon Cloud: A Volatile Resource for High-Performance Computing, IEEE International Conference on Computer and Information Technology, 2015.

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BACKUP

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