Recovery Act:
Yahoo! Compute Coop (YCC): A Next-Generation Passive Cooling Design for Data Centers

Final technical Report

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LIST OF ACRONYMS

Following is a list of the acronyms found in this technical report.

Acronym	Description
AHU	Air Handling Units
ARRA	American Recovery and Reinvestment Act
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BTU	British thermal unit
CAPEX	CAPital EXpenditures
CHW	Chilled Water
CPU	Central Processing Unit
CRAC	Computer Room Air Conditioner
DC	Direct Current
DCiE	Data Center infrastructure Efficiency (%) – PUE is used in this document rather than DCiE
DOE	Department of Energy
DX	Direct Expansion
EPACT	Energy Policy Act of 2005
EPMS	Electrical Power Monitoring System
EYP MFC	EYP Mission Critical Facilities, Inc.
GHG	GreenHouse Gases
GX	GreenXchange
ICT	Information and Communication Technologies
IT	Information Technology
KVA	KiloVolt-Ampere
KW	KiloWatt
kWh	kiloWatt Hours
MW	MegaWatt
OPEX	OPerational EXpenditure
PUE	Power Usage Effectiveness
RH	Relative Humidity
UPS	Uninterruptible Power Supply
YCC	Yahoo! Compute Coop

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1. EXECUTIVE SUMMARY

The purpose of the Yahoo! Compute Coop (YCC) project is to research, design, build and implement a greenfield "efficient data factory" and to specifically demonstrate that the YCC concept is feasible for large facilities housing tens of thousands of heat-producing computing servers.

The project scope for the Yahoo! Compute Coop technology includes:

- Analyzing and implementing ways in which to drastically decrease energy consumption and waste output.
- Analyzing the laws of thermodynamics and implementing naturally occurring environmental effects in order to maximize the "free-cooling" for large data center facilities. "Free cooling" is the direct usage of outside air to cool the servers vs. traditional "mechanical cooling" which is supplied by chillers or other Dx units.
- Redesigning and simplifying building materials and methods.
- Shortening and simplifying build-to-operate schedules while at the same time reducing initial-build and operating costs.

Selected for its favorable climate, the greenfield project site is located in Lockport, NY. Construction on the 9.0 MW critical load data center facility began in May 2009, with the fully operational facility deployed in September 2010. The relatively low initial build cost, compatibility with current server and network models, and the efficient use of power and water are all key features that make it a highly compatible and globally implementable design innovation for the data center industry.

Yahoo! Compute Coop technology is designed to achieve 99.98% uptime availability. The uninterruptible power supply (UPS) system utilizes kinetic stored energy. Each steel-framed pre-engineered building includes an evaporative cooling system for use in the event of extremely high outdoor temperature. This integrated building design allows for free cooling 99% of the year via the building's unique shape and orientation, as well as server physical configuration.

Using the ICT benefits calculator and comparing Yahoo!'s water-cooled, efficient Santa Clara, CA co-location facility to YCC technology, projected U.S. energy savings from 45% market adoption for new data center capacity would be 190 million kWh in 2015 and just over 1 billion kWh by 2020. It is worth noting this is compared to Yahoo!'s high-performing current standard co-location design. If an EPA-stated average of 2.0 PUE is instead assumed, annual savings would be approximately 670 million kWh in 2015 and 3.57 billion kWh in 2020 over current industry averages (with a cumulative 195 billion kWh in 2040 at market saturation).

The Yahoo! Compute Coop technology results are wide-ranging and include:

1.1 Energy Savings

- ~2% annualized "cost to cool" with evaporative cooling; lower in environments that don't require it. "Cost to Cool" is the energy (kW) expended to remove the heat generated by the data center load as a percentage of the data center load itself. (see Table 4-1)
- ~36 million gallons of water saved per year with YCC compared to conventional water-cooled chiller plant designs with comparable IT loads
- Higher efficiency with YCC evaporative cooling design: Target PUE of 1.08-1.11

- ~40% reduction in data center electricity consumption relative to industry-typical legacy data centers.

1.2 Wastewater Elimination

- There is zero data center-related wastewater with YCC technology, which equates to a reduction of ~8 million gallons of sewer discharge per year compared with conventional water-cooled chiller plant design.

1.3 Building Efficiency

- Lower cost to construct than previous designs: Targeting sub- $5M per MW
- Faster to build, with goals to construct and commission pods in less than ~6 months.

1.4 Cost Savings

- Reductions in construction costs.
- Reductions in operating costs.

Yahoo! has already sought patent protection for Yahoo! Compute Coop and related technology, filing several U.S. patent applications and with the intent of seeking worldwide patent protection through the Patent Cooperation Treaty and direct national filings. Additional U.S. patent filings are contemplated. These patent rights will provide a structure for the commercialization effort around the YCC technology in alignment with Yahoo!'s business model.

2. INTRODUCTION

The Yahoo! Compute Coop (YCC) is a critical load cost-effective data center facility designed to take advantage of the natural outside air in order to use less electricity and horsepower by eliminating the need for a traditional mechanical cooling system (other than the evaporative cooling). The YCC's "free-cooling" design successfully addresses the major challenge of reducing data center electricity consumption by significantly lowering the load related to cooling systems.

The advent of pre-engineered buildings and skid-based cooling and electrical systems make YCC technology easy to implement and operate. Front-end costs are significantly lower, and a reduction in overall capital and operating expenses than current best industry practices are realized. The Lockport, NY YCC uses approximately 40% less energy than an industry-typical legacy data center facility.

In a traditional data center application, the cooling system is a supplemental (and highly expensive) necessity of the facility. With the YCC design, the building itself is the air handler: Every aspect of the YCC operates as an integrated part of the total cooling system: The building shape was specifically designed to allow heat to rise via natural convection and the length of the building relative to its width provides easier access to outside air by increasing the area-to-volume ratio. This unique design drastically reduces reliance on electricity, water, and chemical usage, as well as minimizes sewer discharge.

YCC's technology utilizes simple thermodynamic laws and green principles compared to current common data center design practices. Pressure drops are reduced, leading to reductions in fan horsepower requirements. Utilization of free cooling and evaporative cooling, for extreme summer conditions, eliminates the need for expensive, energy-intensive chiller systems & air handling

equipment, thus ensuring that the vast majority of power is allocated to providing useful computing work back to the internet. This approach also translates into fewer moving parts, lower water consumption, and reductions in both capital and operating expenses.

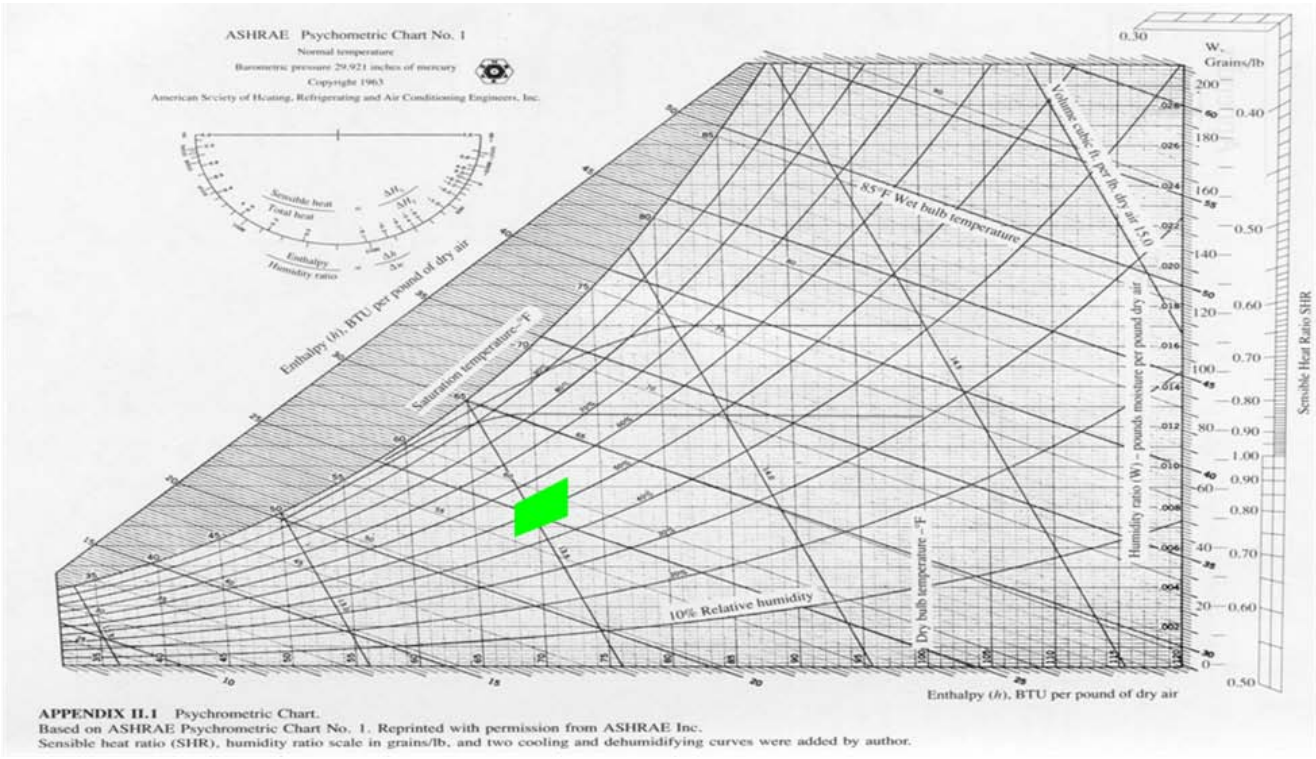
Specifically, the Yahoo! Compute Coop:

- Lowers the "cost to cool" from an industry standard of 54% to ~2%. This translates to a PUE of 1.11 or better – as compared to an industry average of 2.0 PUE, or the 1.27 PUE performance of Yahoo!'s earlier, fairly efficient Quincy, WA data center facility.
- Runs 99+% of the year on free cooling, capitalizing upon local weather conditions.
- Eliminates the need for conventional chiller/air handling units via an evaporative cooling system which is activated only during extreme temperature events.
- Maintains a 99.98% uptime level of reliability for Yahoo! compute servers.
- Maintains the following server room environmental requirements:
  - Room temperature 55°F – 90°F
  - High-end relative humidity; no higher than 85% non-condensing
  - Pressure ±0.11 inches H_20
  - Target design rate of temperature change: 5.4°F per hour
- Withstands 100-year temperature and humidity conditions and extremely low winter temperatures while maintaining server room environmental requirements.

3. BACKGROUND

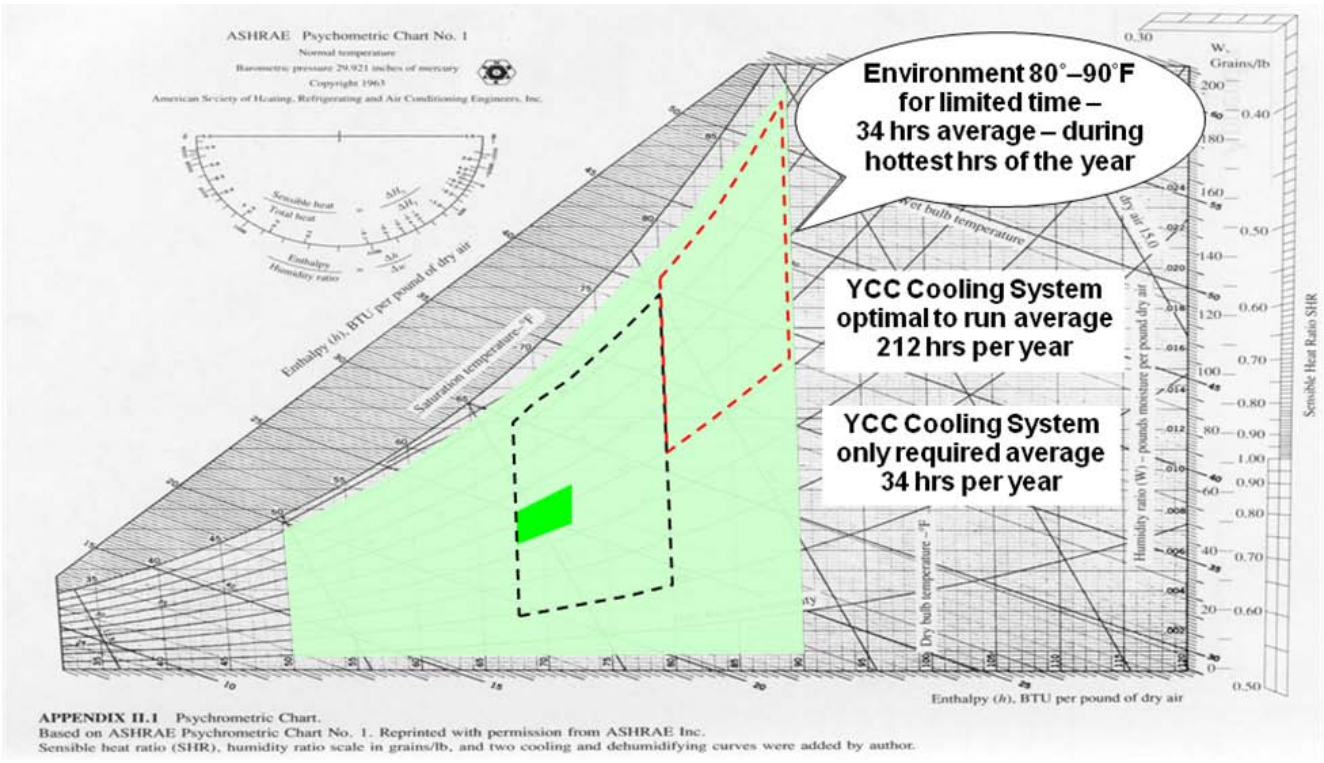
In 2005, a cross-functional team began looking closely at the inefficiencies of data center facility practices and launched an effort to challenge the legacy data center facility temperature and humidification range specifications of 68°–72°F and 44%-55% RH (see Figure 3-1 and Figure 3-2).

Figure 3-1 ASHRAE Psychrometric Chart No. 1 – Illustration of Data Center Facility Legacy Perception



APPENDIX II.1 Psychrometric Chart.
Based on ASHRAE Psychrometric Chart No. 1. Reprinted with permission from ASHRAE Inc.
Sensible heat ratio (SHR), humidity ratio scale in grains/lb, and two cooling and dehumidifying curves were added by author.

Figure 3-2 Yahoo! Compute Coop – New Environmental Specs = Greater Energy Efficiency



After post-conception and design were completed, , a mock-up YCC data center testing lab was built in San Jose, CA. This mock-up was used to test & evaluate various evaporative cooling approaches.

Yahoo! Compute Coop technology offers a simplified whole building design approach – what is a "systems approach" compared to current conventional designs. The design provides lower initial building costs compared with many high-efficiency systems (such as cooling towers, piping for chilled water cooling, etc.). The initial capital cost advantage rests mostly upon the use of a pre-engineered steel building and the elimination of raised floors. These two elements yielded an estimated capital cost reduction of 32% at the Lockport, NY YCC data center facility compared to the 2007 state-of-the-art Quincy, WA data center facility.

Generational steps were taken towards building this more-effective "data factory" by decreasing the cost to cool through simple, green solutions:

- The building was designed specifically to minimize required air flow pressure differentials. This drastically decreased the fan horsepower required to move air through the facility.
- Utilization of naturally occurring outside air for data center facility cooling was tested and proved to be very energy-efficient.
- The implementation of the natural "free-cooling" system eliminated wastewater output.
- Utilization of pre-engineered steel building "pods", elimination of raised floors, and implementation of low-cost underground electrical distribution all combined to provide labor reductions, shorter build times, and lower cost-to-build.

- In 2010, the greenfield-constructed, chiller-less Yahoo! Compute Coop was deployed in the cool, clean climate of Lockport, NY; its immediate, broad energy efficiency successfully challenged legacy temperature specifications.

The benefits are many: The "free-cooling" system design drastically reduces energy consumption; chiller-less, free-cooling technology eliminates cooling tower water usage and subsequent sewer discharge; pre-engineered buildings with, factory built intake and exhaust louvers and dampers arrive ready-to-install; and, shorter time-to-build schedules and lower build costs are realized. All these benefits make the adoption of YCC technology, over more-expensive energy-draining design solutions, a quantified reality.

4. RESULTS AND DISCUSSION

4.1 Technical Innovation

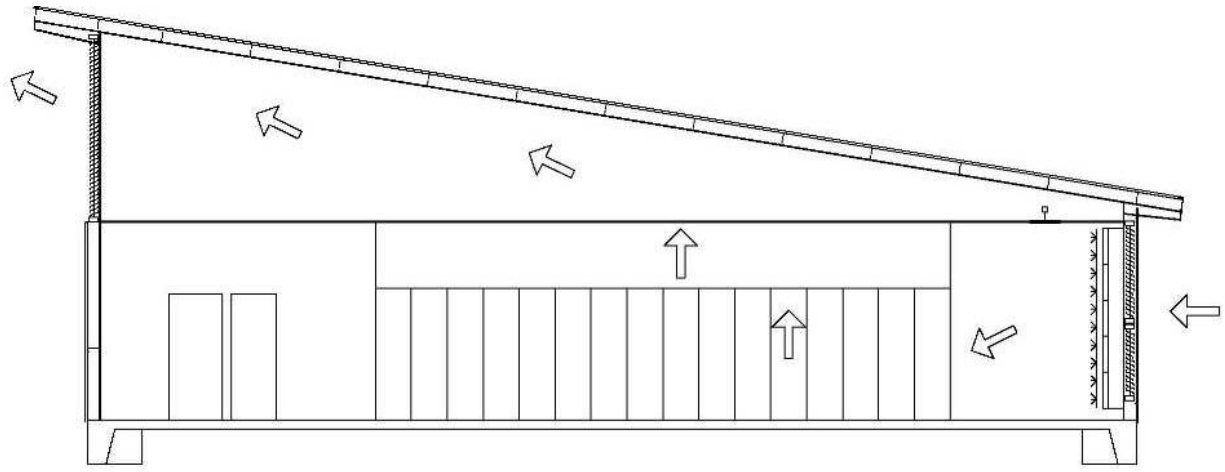
A major contributing factor in choosing the location of Lockport, NY was its ambient weather conditions that are particularly favorable to free cooling. It is estimated that evaporative cooling will only be required for the approximately 212 hours of the year when the temperature is above 80°F, plus an additional estimated 34 hours when the temperature exceeds 90°F (based on annualized averages). For the remaining 8,500 hours per year, free cooling will be the standard.

Under the YCC design, there are three established modes of cooling:

1. 100% outside unconditioned air cooling
2. 100% outside air tempered by evaporative cooling
3. Mixed outside air cooling

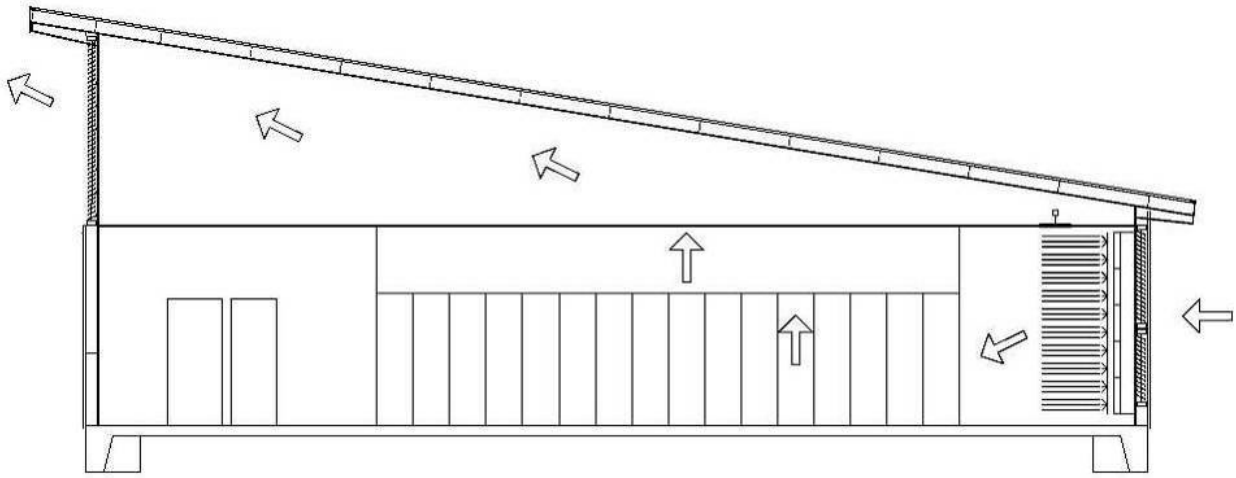
These cooling modes are illustrated in Figure 4-1, Figure 4-2, and Figure 4-3, below.

Figure 4-1 100% Outside Unconditioned Air Cooling Mode



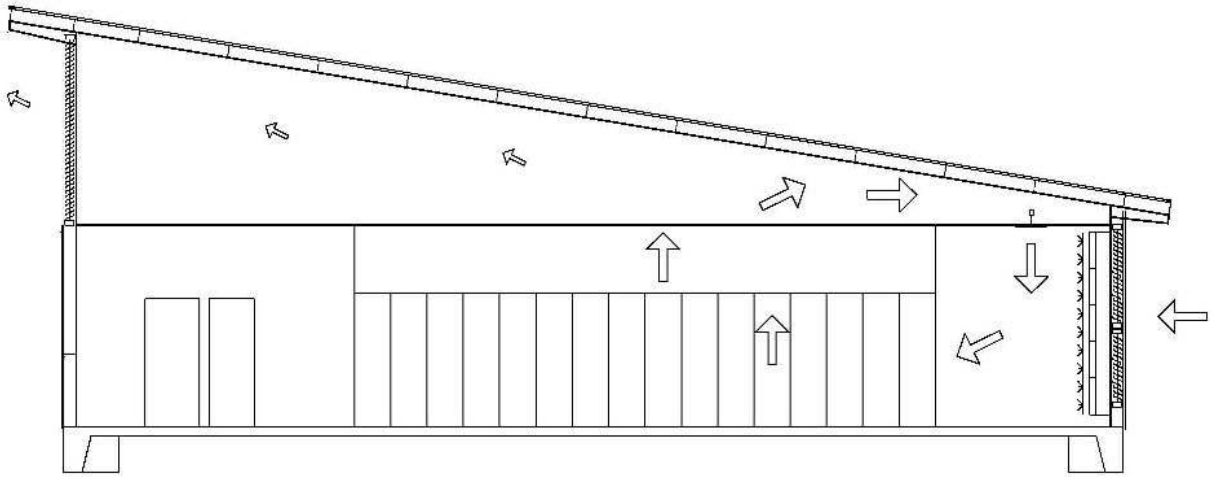
During this mode, 100% outside air is used between the temperatures of 70°F up to 85°F, with the air entering the facility through a louvered outer wall, which is then filtered and drawn through the servers. The air is exhausted by natural convection from the enclosed attic space through exhaust louvers.

Figure 4-2 100% Outdoor Air Tempered by Evaporative Cooling Mode



In this mode, the air takes the same path as the aforementioned 100% outside air mode except that shortly after entering the outer louvered walls, it is drawn through saturated media in order to provide evaporative cooling to this incoming hot air. The outside air conditions during this mode are 85°F to 110°F.

Figure 4-3 Mixed Outside Air Cooling Mode



During winter when exterior air conditions drop below 70°F, a portion of the air exhausted through the servers into the attic space is mixed with the incoming outside air to achieve a mixed-air temperature of 70°F. This is accomplished through return air fans placed in the false ceiling near the outside air intake. There is a recirculating air fan in the space to help blend the mixing air, preventing any temperature or humidity gradients.

4.2 Building Specifications

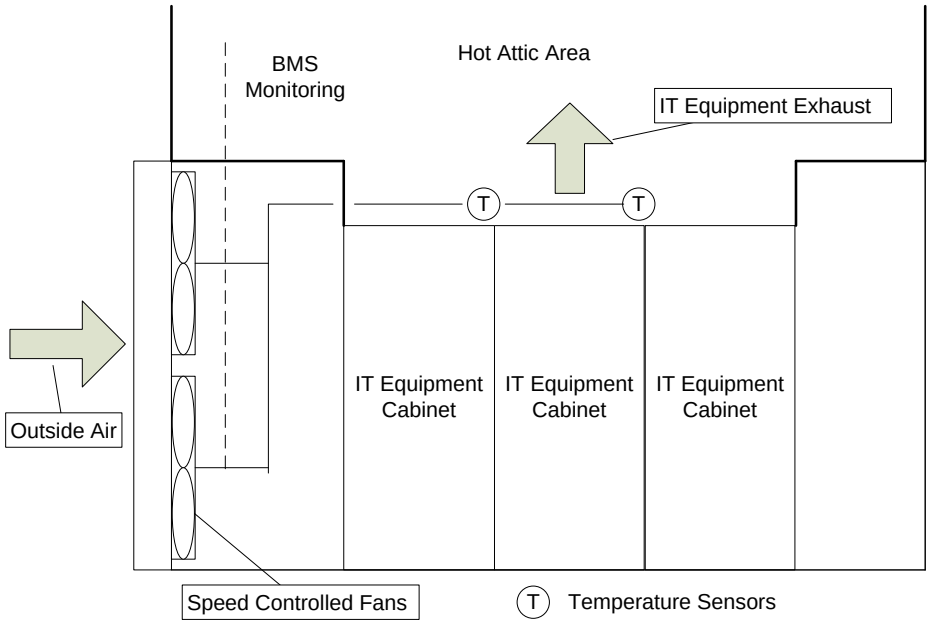
The building type is a long, tall 120' x 60' commercial metal-style building. All sections of the lower wall on one side and the upper wall on the opposite side are almost completely louvered to allow air to enter and exit the building. The roof is a shed style with a 2:12 pitch, sloped to a degree that allows snow to build up and melt, with heat from the server room accelerating the snow-melting process.

The building has been specifically designed to take advantage of warm air's tendency to rise... This natural "drafting" enhances the mechanically induced movement of air and therefore reduces the overall fan horsepower necessary for cooling the data center.

4.2.1 Fan Control System

The goal of the fan control system is to maintain a properly mixed server supply air temperature between 70°F and 85°F and a non-condensing relative humidity below 85%. Fan speeds are regulated based on hot aisle temperature via speed controlled fans. The return mixing dampers are only in operation when temperatures are less than 70°F. The fans are designed to keep air turbulence high, which helps mitigate temperature gradients and induce mixing. Outside air temperature & humidity, as well as cold aisle temperature are monitored providing an indication of outdoor and return air mixing efficiencies. Dew point sensors are used in conjunction with evaporative media to ensure additional moisture is not added to already saturated air.

Figure 4-4 Fan Control System



4.3 Efficiency Gains

For the 9 MW of critical load in the initial buildout of the Lockport, NY YCC, Yahoo! anticipates reduced energy consumption of 8.6 million kWh per year measured against the Quincy, WA data

center facility built in 2006. Compared to an efficient but conventional collocated facility (such as the one Yahoo! currently occupies in Santa Clara, CA), a savings of 18.9 million kWh is estimated.

Note: Yahoo! reviewed DCPro tool as recommended for the purposes of calculating efficiency benefits of YCC. However, since the majority of inputs assume a centralized cooling system, the team concluded the tool was not appropriate for this design. We have instead provided the calculations below to explain our expected efficiency gains.

See Table 4-1 and Table 4-2 for a breakdown of the progression of cooling and electrical efficiency over time

Table 4-1 Breakdown of Cooling Efficiency by Data Center Design Year

	2005	2006	2006	2007	2010
Type of System	Standard CRAC; no economizing; DX cooling system	Water cooled site built chiller plant; standard CRAC; no economizing	Air cooled chiller plant; AHU with outside economizing	Modular, tuned chiller plant; next-gen AHU with outside air economizing	Yahoo! Compute Coop
Site Example	Yahoo! colocation site in Santa Clara, CA	Yahoo! colocation site in Santa Clara, CA	Yahoo! existing data center facility in Wenatchee, WA	Quincy, WA Phase 1	Lockport, NY
KW per ton AHU	0.50	0.50	0.40	0.35	0.10
KW per ton CHW	NA	0.75	1.15	0.68	0.03
KW per ton CHW during free cooling			0.10	0.06	0
KW per ton DX	1.38	NA	NA	NA	NA
EXAMPLE electro / mechanical load KW	5,000	5,000	5,000	5,000	5,000
Tonnage requirement	1,420	1,420	1,420	1,420	1,420
KW AHU (max)	710	710	568	497	142
KW AHU best (free cooling)	N/A	N/A	142	85	0
KW AHU average	710	710	355	291	71
KW heat removal max (DX or CHW)	1,960	1,065	1,633	965	42
KW heat removal best (free cooling)	–	–	142.05	85.23	0
KW heat removal average	1,960	1,065	958	568	21
Total cooling load KW per MW DC load	**2,670**	**1,775**	**1,313**	**859**	**92**
% of Total Cooling	**53%**	**36%**	**26%**	**17%**	**2%**

Table 4-2 Breakdown of Electrical Efficiency by Data Center Design Year

	Yahoo! Colocation Data Center Facility – Santa Clara, CA (2006)	Yahoo! Data Center Facility – Quincy, WA (2007)	Yahoo! Compute Coop (YCC) Data Center Facility – Lockport, NY (2010)
True server load (watts): equivalent performance – 2 CPU cores; 4GB RAM; 1 80 GB HD	140	89	89
Power supply efficiency loss (watts)	215	93	93
Dist / server voltage transformation loss (watts)	222	–	–
UPS efficiency loss (watts)	252	99	97
Medium voltage transformation loss (watts)	257	101	99
Total power per example server (watts)	257	101	99
KW cost to power 25,000 servers (without cooling)	6,438	2,529	2,489
KW cost to cool servers	2,285	434	46
Total KW cost for 25,000 servers	**8,722**	**2,963**	**2,535**
Total KW power savings versus Santa Clara CoLo		**5,759**	**6,187**
PUE	**1.62**	**1.27**	**1.08**

Represents a **70%** improvement over the Yahoo! Santa Clara, CA colocation facility when improvements in all components in electrical efficiency path are included.

Table 4-3 shows the energy and carbon savings utilizing YCC technology compared to prior designs. In addition, minimized use of evaporative cooling as compared to standard cooling methods is predicted to yield a 99% reduction in water use at the facility (and a corresponding reduction in wastewater outflow) as compared to a traditional data center that uses water cooled chillers.

The carbon savings below assumes an average U.S. carbon intensity of 0.56 tons CO_2/MWh. In reality, our carbon reductions will be much lower by virtue of how clean electricity is in all three sites (0.31 tons CO_2/MWh for Santa Clara, and close to zero for both WA state and upstate NY).

Table 4-3 Energy and Carbon Savings Utilizing YCC Design Compared to Prior Designs (Based on cooling efficiency gains only)

	Yahoo! Colocation Data Center Facility – Santa Clara, CA	Yahoo! Data Center Facility – Qunicy, WA	Yahoo! Compute Coop (YCC) Data Center Facility – Lockport, NY
PUE	1.62	1.27	1.08
Relative energy savings for a 9 MW YCC plant (kWh/year)	26,541,307	12,094,773	–
Average annual carbon savings (tons CO_2)	14,863	6,773	–

5. BENEFITS ASSESSMENTS

5.1 Overview of Measurement and Verification Activities to Obtain PUE

For all Yahoo! Data Centers, Power Usage Effectiveness (PUE) is obtained by measuring the system utility power input and the critical power consumption as close as possible to the server loads. This information is read and collected from the installed Electrical Power Monitoring System (EPMS) using power circuit monitors. Since both Data Centers in this test case extensively utilize outside air cooling methods, data will be collected on a monthly basis and annualized to account for variables such as weather, operating hours, etc.

5.1.1 Yahoo! Data Center Facilities Examination

For this verification plan, two Yahoo! data center facilities are being examined:

- **Yahoo! Data Center Facility – Wenatchee, WA**
  - **Site Description:** The existing installation at Wenatchee has proven to be the most efficient Yahoo! data center prior to 2010. Located in central Washington, the site was selected for its climate, with the existing building optimized to take advantage of outside air economization. Air

handling units (AHU) discharge into a traditional raised floor plenum, distributing supply air to the servers.

- **Installation Date:** 2006
- **Electrical:** 4.8 MW, N+1 critical infrastructure with 4,800 KW static battery UPS and 4 x 2 MW diesel generator back up.
- **Cooling System:** Air Cooled Chillers and AHUs with outside air economizing.
- **Designed Target PUE:** 1.25

- **Yahoo! Compute Coop (YCC) Data Center Facility – Lockport, NY**
  - **Site Description:** The innovative design and installation of the Yahoo! Compute Coop at Lockport is the most efficient of all Yahoo! data centers to date. Located in Lockport, NY, the greenfield site was selected for its cold climate; its unique design exclusively incorporates outside air economization, significantly reducing supply fan horsepower.
  - **Installation Date:** 2010
  - **Electrical:** 9 MW, N+1 critical infrastructure with line interactive UPS systems using kinetic stored energy and diesel generator backup. Primary UPS systems are deployed in 200KW modules, allowing systems to be taken offline when not in use.
  - **Cooling System:** Yahoo! Compute Coop integrated building system cooling with evaporative cooling.
  - **Designed Target PUE:** 1.08 – 1.11

5.1.2 PUE Calculation

PUE is calculated using the following:

$$PUE = \frac{Total\ Facility\ Power}{IT\ Equipment\ Power}$$

- IT Equipment Energy: Comprehensive energy use associated with all of the IT equipment; i.e., computer, storage and network equipment along with supplemental equipment.
- Total Facility Energy: All facility energy use including IT Equipment Energy, Electrical Distribution Losses, cooling system energy, fuel usage, and other miscellaneous energy use.

For this study, the Yahoo! Wenatchee Data Center facility is being used as the baseline to which the Yahoo! Lockport Compute Coop design will be compared.

Given that the Lockport data center was deployed in September 2010, the YCC facility has not yet reached its maximum capacity as of February 2011; values taken during the commissioning period will be used as a snapshot, with additional data to be taken over the course of a one-year period for comparison.

5.2 PUE Performance Period Verification Activities

Where applicable, information for Wenatchee and Lockport data centers shall be collected over a period of 1 year (from June-2011 – May-2012). PUE shall be averaged every 30 days during the verification period.

The electrical power consumption shall be collected via EPMS and will include the following:

- Utility energy use metered at Utility Mains using Square D CM4250 power quality meter or equal.
- UPS system output energy use metered at the 480V output switchboards using Square D CM4250 power quality meter or equal.
- Critical Power metered at 120/208V feeders to plug-in busway using Square D ION power circuit monitors or equal.

For each power meter, the following information will be collected by the EPMS and averaged for a 30 day period to determine PUE:

- A-B-C Amps
- KW
- KVA

For each diesel engine generator, fuel consumption shall be recorded. Diesel engine testing shall be performed while supporting IT loads when applicable. The recorded fuel consumed shall be converted to BTU and KW in accordance to the manufacturer's published performance data.

Refer to the following attachments for power meter locations and data obtained:

- Yahoo! Lockport Single Lines
- Yahoo! Lockport Generator Performance Data
- Yahoo! Wenatchee Single Lines
- Yahoo! Wenatchee Generator Performance Data

6. COMMERCIALIZATION

Three major areas of data center design practices have been slow to adopt innovation due to the perception of increased risk. They are:

1. The use of outside air for cooling;
2. Concern around exceeding ASHRAE temperature & humidity standards for servers;
3. The willingness to eliminate expensive, large mechanical cooling systems entirely from the design.

The EPA's 2007 *Report to Congress on Server and Data Center Energy Efficiency* noted that risk aversion was one of three major barriers to efficiency adoption in the industry: "Energy efficiency is perceived as a change that, although attractive in principle, is of uncertain value and therefore may not be worth the risk. (p. 12)."

The lack of publicly available examples of these types of design innovations being used successfully has limited the experimentation and aggressive adoption of these design practices. With the deployment of the YCC design, Yahoo! has addressed all three areas of concern and has evidence to prove their effectiveness.

Yahoo! expects the innovative YCC design will accelerate global adoption of all three design practices both directly and indirectly. The actual design and execution of this project by a publicly traded, well-recognized company that requires large data centers to run with an extremely high level

of reliability will drive interest in and adoption of the specific design. At the same time, this example will also reduce risk aversion within the data center industry (both data center designers and IT equipment manufacturers) for other innovations that relate to free cooling, chiller-less data centers, and broader temperature ranges – as well as experimenting with designing data centers with closer attention to maximizing the use of local climate conditions.

At the time of this report, the YCC patent is being reviewed by the USPTO.

7. ACCOMPLISHMENTS

Yahoo! has already sought patent protection for YCC and related technology, filing several U.S. patent applications and with the intent of seeking worldwide patent protection through the Patent Cooperation Treaty and direct national filings. The patents are currently under review by the USPTO. Additional U.S. patent filings are contemplated.

A great deal of wide-ranging, positive press coverage surrounded the September 2010 deployment of the YCC data center facility in Lockport, NY:

- **Total Print/Online** – 60 Original Articles and 95 Reposts
- **Total Press Release Coverage** – 52 Press Release pick-ups
- **Total Social Media/Tweets** – ~1,000+ Total Tweets, including ~36 Media Tweets

7.1 Key Headlines

- Yahoo! Opens Data Center in NY, Will Employ 100 – **Associated Press**
- Yahoo! Opens Doors to Self-cooled Data Center – **CNET**
- Yahoo!'s Green Data Center is Designed Like a Chicken Coop – **Fast Company**
- Yahoo! Nears Perfection With Chicken Coop Data Center – **Greentech Media**
- Yahoo!'s New Facility Shows Growing Importance of Green Data Centers – **VentureBeat:GreenBeat**
- All Cooped Up: Yahoo!'s Novel Green Data Center Design – **ZDNet**

7.2 Notable Media Quotes

- "The data center really does have to transition from being this niche facility into a real efficient factory, just like any other manufacturing facility," Noteboom said. "We're manufacturing bits versus other industries that may manufacture cars or electricity." – **Associated Press**
- Yahoo!'s VP of Data Center Engineering & Operations Scott Noteboom compared the design innovation of the Coop to a technology disruption as large as Henry Ford's automation of the auto factory in an interview with me last week. Yahoo! can get a lower cost to build and run a Coop; it's more energy-efficient; and it's more simple and quicker to build than traditional data centers, said Noteboom. – **GigaOm**
- "For the past 60 years data centers were always this niche area that didn't evolve very much, they were pretty expensive and slow to build. This represents a major shift of turning the data center into a highly efficient data factory," said Scott Noteboom, Yahoo!'s vice president for data center engineering and operations. – **IDG**

- According to Page, the green design of this data center is a win-win: "By owning, designing and building these energy-efficient data centers, it's good for our bottom line and better for the environment," Page said. – **GreenBiz**

8. CONCLUSIONS

A 2007 EPA study, *Report to Congress on Server and Data Center Energy Efficiency*, assumes that data centers will consume 100 billion kilowatt-hours of electricity by 2011. If only 476 MW of new capacity – less than 10% – were to be built between 2007 and 2011 using the YCC technology as opposed to less-efficient current designs (at a respectable 1.35 PUE), an estimated 1 billion kWh of savings could be realized. Future adoption could easily exceed this result by several times over.

By taking advantage of climate and facility placement, YCC's chiller-less, free-cooling technology has many benefits over current industry standards. Its pre-engineered building pods and skid-based cooling and electrical systems are less-expensive, easier-/faster-to-construct, and more-efficient to build. Simple design principles and green heating/cooling technology results in immense energy savings and decreased pollution.

With demand for data center capacity continuing to accelerate, both the content and the timing of the YCC provide unique game-changing opportunities.

At the time of this report, the YCC patent is being reviewed by the USPTO.

Yahoo! is currently moving forward with implementing the design in new pre-engineered building in the central Washington area as well retro-fitting the YCC concept into a data center build in a pre-existing building in Europe.

9. RECOMMENDATIONS

None

10. REFERENCES AND BIBLIOGRAPHY

- American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) "Psychrometric Chart No. 1, Normal Temperature," page 44, *ASHRAE Standard: Standard Method Test for the Evaluation of Building Energy Analysis Computer Programs*, 2004.
- U.S. Environmental Protection Agency (EPA) ENERGY STAR Program, *Report to Congress on Server and Data Center Energy Efficiency*, August 2007.

11. APPENDIX A: SUPPLEMENTARY MATERIAL

Supplementary Material

Figure A-1 Yahoo! Compute Coop Data Center Facility – Lockport, NY

Figure A-2 Buffalo, NY Factory Building – Inspiration for YCC Technology

Figure A-3 Yahoo! Compute Coop Data Center Testing Lab – San Jose, CA

Figure A-4 Yahoo! Compute Coop's Skid-Based Cooling System – Lockport, NY

Figure A-5 Yahoo! Compute Coop's Server Aisle Build – Lockport, NY

Figure A-6 Yahoo! Compute Coop's Server Aisle – Lockport, NY

Figure A-7 YCC Louvered "Coop" Design – Lockport, NY

Figure A-8 Yahoo! Compute Coop Data Center Facility– Lockport, NY

Figure A-9 Yahoo! Compute Coop Data Center Facility – Lockport, NY