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Energy Efficiency Improvements in the Campus Data Centre

Improving energy use efficiency in the campus Data Centres supports the campus sustainability plan and reduces operating costs. This investigation considered opportunities for better energy management in the campus Data Centres to reduce operating costs and support the University's Sustainability Plan.

To date, energy use has not been monitored so explicit energy management has not been possible. Instrumentation to monitor energy use at the macro and component levels must be deployed to measure consumption and efficiency, and to verify success of operational improvements.

Short term energy management measures include

- accelerating virtualization combined with early shutdown of older servers,
- implementing operational practises to power down idle systems, and
- upgrade of the cooling systems to improve efficiency.

Improvements to IT systems designs are strategic but provide small incremental improvement over time. These activities will not attract much additional funding.

The cooling systems, a major source of energy waste, will require re-design and investment to realize better efficiency. A longer term plan to reduce energy use for cooling could attract additional funding through the Physical Resources' Energy Conservation Program.

Before adopting these longer term measures a critical study of the future (5 year projection) of the data centre should be undertaken to determine energy requirements for the Data Centre.

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Executive Summary

This investigation considered opportunities to improve energy use efficiency in the campus Data Centre complex operated by CCS. An analysis of the Data Centre systems and their current energy use was compared with current industry best practices to produce a set of improvement recommendations. They include

- immediate low-cost operational changes to reduce energy waste,
- limited-cost tactical changes to improve monitoring and manageability of energy use, and
- longer term strategic plans, with significant project costs, to evolve the Data Centre to optimal best practices and an improved cooling system.

Current Energy Use

ANS DC	**$290,000**
CUP CW	**$96,000**

As a comparison,
- *campus electrical consumption was about **$10 M** last year.*
- *Library energy retrofit <u>saves</u> about **$200,000** per year.*

The cost of electrical energy consumed for the ANS Data Centre operation is estimated **$386,000/yr**. Of that, an estimated **25%** is used at the Central Utilities Plant (**CUP**) to supply Chilled Water for cooling to the Computer Room Air Conditioner (**CRAC**) units**.**

within ANS DC	
CCS Systems	**20%**
Dept Co-locate	**9%**
SHARCNET	**35%**
Cooling; other	**36%**

Within the ANS Data Centre, energy use is divided between cooling and other facility systems consume, the SHARCNET High Performance Computing servers and storage, and the CCS-owned and departmental co-located servers.

Based on the above data, the Power Utilization Efficiency (**PUE**) is about **2.12** indicating the Data Centre uses energy reasonably efficiency. Improvements should target a PUE of about **1.6**.

Energy Capacity

Both the Data Centre electrical supply and the cooling systems have adequate supply for significant growth. With SHARCNET expected to leave in 2-3 years, anticipated growth should not be limited by capacity.

	Current Load	w/o SHARC
Electrical	**50%**	**20%**
Cooling	**58%**	**36%**

While the electrical capacity can be handled by the current 3 UPS units, they do not provide full redundancy. When SHARCNET is removed, the redundancy level can be improved. While the CRAC circulation fans provide adequate cooling and potential air flow, poor room air flow management and inadequate cabinets reduce room heat exchange capacity.

Observations and Operational Issues

- Server virtualization is providing energy reduction. Since February, CCS IT server load has reduced by 8%. At the same time, the SHARCNET load has grown by 14%.
- The most significant contribution to waste in a Data Centre is the energy consumed by idle systems. There is no *in-activity* monitoring being done to determine ANS DC server idle time and no processes to shutdown *in-active* systems.
- Server technology 4 years or older consumes 50-100% more energy than current technology specifically designed with energy management controls. Replacing older systems ASAP can save 20% of the Current IT systems energy.

- All CRAC units are operating inefficiently because the low temperature set-points, lack of balance and poor air management (hot-cold mixing).
- ANS 033 is operating near critical cooling because of air management inefficiencies. The most significant problem is in-effective air management around the SHARCNET complex. ANS 033A has some cooling problems because it is operating inefficiently at well below capacity.
- The 6 down-flow CRAC units have more than enough air flow capacity to cool the centre to its electrical capacity. For low density racks, additional fan/cooling units are not needed. However, the current room layout wastes most of the airflow capacity.
- Because much of the cooling system energy use is fixed (e.g. fans run 24x7), additional reduction of the IT systems energy consumption will make the Data Centre appear less energy efficient (i.e. PUE will increase).
- As part of their Building Automation System (BAS) plan, Physical Resources are developing monitoring systems for electrical and Chilled Water building systems. The ability of the BAS to monitor and report on some Data Centre facilities was demonstrated.

Opportunities for improvement

Operational Improvements

- Accelerate migration to virtual servers to remove older server technology.
- Develop a process to identify and shutdown idle, non-critical components, especially out of business hours.
- Reduce CRAC unit energy waste by disconnecting re-heaters and by increasing and balancing the set-point temperatures to eliminate the normal operation of the compressors.
- Install curtains to contain air in hot-cold aisles of SHARCNET facility to improve efficiency of XD cooling. Consider curtains for some aisles in Rm. 033A.
- Where possible, move CCS servers from 033 to 033A to balance heat load.
- Pilot CCS online monitoring of an UPS and a CRAC unit.

Tactical Projects

- Continue Virtualization strategy to improve utilization of servers. Add energy management control software to reduce idle processors.
- Develop better tracking of systems in the Data Centre, coupled with captured utilization information, to improve ability to track and report on energy use.
- Monitoring is the key to energy management.
  - Consider energy monitoring as a requirement for all new server chasses.
  - Replace current Cabinet power-bars with rack PDU’s with built-in monitors.
  - Develop a plan with Physical Resources for active facilities monitoring.
- Consolidate new server chassis in a limited floor area rather than them spreading out. Implement load cost air flow management with curtains and under floor baffles. Reduce the number of active CRAC units, keeping idle units for backup.

Strategic Planning

To achieve optimal energy use, the data centre layout and cabinetry must be re-organized and CRAC units replaced with more efficient units. With virtualization and a hardware strategy, opportunities for high power density design are possible, saving significant space and further reducing energy waste.

Before embarking on projects of significant cost and effort, a strategic plan for the future of the data centre should be developed. It would include consideration of cloud-based services, the Data Centre support of IT for research, and the potential for cooperative shared facilities with neighbouring universities and other public sector institutions. The plan would identify the anticipated growth of data centre and intended use of the spaces.

Based on this Strategic Plan, a more energy efficient data centre design, with better room layout (hot/cold aisles) and appropriate cabinets for efficient .

Johnston Hall Server Room

A detailed analysis of the energy systems of this Server Room was not done. However, energy management, especially cooling, suffers from similar problems as the ANS Data Centre. Specifically

- The large room and equipment layout results in very poor airflow management. With a high level of mixing the CRAC units are very inefficient.
- During the summer, heat infiltration adds cooling load.
- The old CRAC units are well beyond end of life. The Chilled Water supply has control problems.
- The small sack-size UPS units are operating at low utilization; this type of unit is very inefficient at low utilization resulting in low energy efficiency.

Tactical Plan

- Develop a plan to re-organize the IT systems equipment layout into hot-cold aisles with flow through cabinets. Orient for efficient air low to CRAC units.
- Install a well insulated temporary wall to reduce the cooled area to a minimum. Moving the wall can provide future expansion. Insulate the external wall window area.
- Replace the small UPS units with a Room UPS.
- Working with Physical Resources, determine the CS problem and cost a solution. (Physical Resources can provide Chilled Water more inexpensively than using a local refrigeration-type unit. A local CRAC also requires an outdoor condenser; its location in a cool (non-sunny) location may be difficult to find.)
- Replace obsolete CRAC units with 2 (for redundancy) small Chilled Water up-flow units, based on anticipated heat load. 2 8-ton (25 kW) CW-hybrid units recommended.

Funding Opportunity

- The scale of energy savings through virtualization and refresh of IT components is small compared to planned campus energy retrofits. A Data Centre retrofit proposal would have to include major changes with significant savings to compete for funding.
- Reduction in the use of Chilled Water can result in significant savings at the CUP. As part of a strategic plan, CCS measures to reduce CW may be funded centrally from the identified savings. More investigation with Physical Resources is required to determine whether Data Centre load reduction impacts the CUP.
- Physical Resources (PR) is implementing more energy monitoring, both on electrical plant and the CW plant. Working with PR, CCS could expand monitoring around the Data Centre to utilize PR BAS monitoring and reporting instead of a separate DC monitor.

Energy Efficiency Improvements in the Campus Data Centre

Request

Opportunities exist to improve the energy efficiency ("greening") of our Data Centre to reduce CCS and University energy costs. There is a large body of knowledge about the design of efficient data centres in higher education institutions. There may also be opportunities to leverage energy conservation project funding to improve the Data Centre as part of the University's overall Energy Conservation program.

This review was to build on past analysis of our data centre to identify opportunities

1) to monitor the impact of changes in the data center on energy efficiency and
2) to identify limited cost solutions to improving energy efficiency now, and
3) to identify funding opportunities for major efficiency improvements.

Emphasis was to be given to objective #2 – low hanging fruit.

Initially the investigation was to focus on the ANS Data Centre which has the largest energy use and supports our mission critical systems. However, the request was expanded to include the Johnston Hall Server Room because of its age and state of maintenance.

Investigation

The investigation considered past proposals for data centre improvements, gathered state-of-the-art design concepts from a number of consultants, and developed a model of energy use in our data centre. Reports and email from other universities who have made data centre energy management improvements were also considered.

Consultant Input

Scoping and focus was developed with a Gartner Data Centre consultant. Notes from a 2008 consultation with IBM data centre specialists were reviewed. Several conversations were held with project consultants at BRUNS-PAK, a large firm specializing in data centre design construction were held to determine the approach and costing for a major data centre energy management study and recommendations.

Input on energy use and monitoring was also sought Physical Resources. With the assistance of Dan MacLachlan, Director, Maintenance and Energy Services, and George Lopers, Controls Manager, Physical Resources, a controls consultant provided estimates of current energy consumption and recommendations for better monitoring and operational improvements.

Investigation of Energy Consuming systems

The configurations of energy consuming systems of the Data Centre were investigated. Concerns about current operation, opportunities for reduced energy use, and required changes are identified are considered with potential savings and project costs to determine prioritization.

1. *Computational efficiency / virtualization*
2. *IT equipment renewal planning*
3. *Energy conservation operating practices*
4. *Efficient electrical power delivery and distribution*
5. *Efficiently cooled room design*
6. *Efficient Cooling systems*

Observations

Observability

"If you can't measure it, you can't manage it" is very true for energy systems. The University and especially the Data Centre has very few energy monitoring instruments so energy use was hard to determine. Neither CCS nor Physical Resources are doing any continuous energy use monitoring at the Data Centre or the mechanical rooms.

The UPS units provide a composite measure of instantaneous electricity use by the IT systems. Other electricity use by the fans, cooling systems, etc. was estimated from instantaneous measurements of supply circuits (by PR consultant). Other factors, including electrical losses and power factors were assumed from product literature.

Energy use is varies or is periodic for some systems but there is no record of use over time. Very rough estimates of use over time were used to determine an annual consumption budget for all equipment. Both the UPS and CRAC units have the capability of being monitored via network connections.

Although a spreadsheet record of Data Centre IT components is maintained, it lacks information and it was difficult to extract some information (e.g. utilization levels, equipment ownership, …). An asset database would be much more helpful.

Energy System Observations – ANS Data Centre

The ANS Data Centre energy systems are outlined in the diagram in Appendix 1.

Energy Use in the ANS Data Centre (see appendix 2 for details)

- The annual total energy consumption is **3,860 MWh** ($386,000), including supply of Chilled Water from the CUP (**25%**).
- The annual total electrical consumption in the Data Centre is **2,900MWh** ($290,000) of which about **63%** is used to power IT Servers.
- From records it appears that about 30% of the load on the CCS UPS units is from co-located equipment. Energy consumption in the Data Centre therefore breaks down as
  - CCS-owned systems **20%**....................**580 MWh** ($58,000)/yr.
  - Co-located departmental systems **9%**
  - SHARCNET consumes about **35%**
  - … Cooling and other loads **36%**
- The Power Utilization Efficiency (**PUE**) is about **2.12** indicating the Data Centre uses energy *reasonably efficiency*.
- Improvements should target a PUE of about **1.6**.

Note:

Because much of the cooling system energy use is fixed (e.g. fans run 24x7), additional energy efficiency improvements of the IT systems will result in the Data Centre appearing less energy efficient (i.e. PUE will increase).

Capacity of the ANS Data Centre (See appendix 3 for details)

- The supply of generator-backed electrical power is a critical capacity limit. The SHARCNET feed does not use this supply.
- Currently the Data Centre consumes about **50%** of the generator-backed supply.
  - Because the CRAC unit load will not increase significantly, this reserve capacity would be directed mostly to IT equipment.
- Cooling capacities are room based.
  - Rm 033 (with SHARCNET) is utilizing **88%** of the room capacity.
  - Rm 033A is utilizing only **38%** of room capacity.

Operational Observations – ANS Data Centre

See Energy Use Summary in Appendix 3

1 . Computational efficiency

The Power Utilization Efficiency number measures how power is effectively delivered to servers. It does not measure how effectively that power is used at the servers. Since computation units and, to a large extent, storage devices use energy at the same rate whether idle or productively executing applications, server energy efficiency is highly rated to utilization.

CCS is not monitoring and reporting overall utilization rates so it is not possible to estimate energy efficiency in terms of applications.

Idle systems, with not active applications, available for develop, or running applications of only short periods of the day, waste energy at a significant rate. CCS does not have processes to keep track of these systems, not procedures for shutdown of idle systems.

2. IT equipment renewal planning

Server technology 4 years or old consumes 50-100% more energy than current technology specifically designed with energy management controls. Replacing older systems ASAP can save 20% of the Current IT systems energy.

3. Energy conservation operating practices

The most significant contribution to waste in a Data Centre is the energy consumed by idle systems. There is no *in-activity* monitoring being done to determine ANS DC server idle time and no processes to shutdown *in-active* systems.

As part of their Building Automation System (BAS) plan, Physical resources are developing monitoring systems for electrical and Chilled Water building systems. The ability of the BAS to monitor and report on some Data Centre facilities was demonstrated.

CRAC unit #6 has a network connectable monitoring device. The other units can be retro-fitted economically. Consideration should be given to a central control device that synchronizes the 3 units in ANS 033A to minimize contention. An optional network interface can be added to the Mitsubishi UPS units.

4. Efficient electrical power delivery and distribution

Electrical supply systems contribute to small energy losses however, traditional room-based cooling systems are highly inefficient.

5. Efficiently cooled room design

- All CRAC units are operating in-efficiently because the low temperature set-points, lack of balance and poor air management (hot-cold mixing).
- Short circuiting of the air flow (hot-cold mixing) results in cool air return to the CRAC units, significantly decreasing the efficiency of the heat exchanger. This also results in over-cooling - cold outlet temperatures – causing the re-heaters to be on … a significant energy waste.
- The low room set-point results in very cold CRAC outflow temperatures. Since they are below midpoint, significant condensation occurs, in some instances resulting in dampness under the CRAC units. The humidity I the room is quite low. However, the CRAC humidifier units are not operational (no fuses!). Slightly higher humidity would be better for the room but this would increase energy use. A higher set-point (outflow temperature above 58° F) would improve humidification.
- ANS 033 is operating near critical cooling because of air management in-efficiencies. The most significant problem is in-effective air management around the SHARCNET complex. ANS 033A has some cooling problems because it is operating inefficiently at well below capacity.
- The 6 downflow CRAC units have more than enough air flow capacity to cool the centre to its electrical capacity. For low density racks, additional fan/cooling units are not needed. However, the current room layout wastes most of the airflow capacity.
- AC#2 is very inefficient because it is located on a 6" raised floor preventing good air flow. Placement of IT systems in this section of Rm 033 should be discontinued. The Red UPS can be cooled with an air duct. AC#2 can be removed or relocated.
- Because AC#4 and the XD cooling system operate from the SHARCNET feed, there is a Business Continuity risk should the SHARNET feed be down for a considerable period.

6. Efficient Cooling systems

The constant energy load design of the cooling system will increase inefficiency as IT systems become more efficient! Replacing the current cooling system in ANS can reduce energy waste significantly.

Energy System Observations – Johnston Hall Server Room

1 . Computational efficiency

The systems in Johnston were not investigated in detail. However,

- Many of the servers are appliance-type systems with limited operational mechanisms for improved efficiency. As these systems are replaced, energy efficiency should be a selection criterion.
- Some systems mirror servers in the ANS Data Centre and would be upgraded with energy efficiency plans in ANS.

2. IT equipment renewal planning

Not investigated.

3. Energy conservation operating practices

There is no energy monitoring in the Johnston Hall Server Room.

All systems operate 24x7; no idle system shutdown is done.

4. Efficient electrical power delivery and distribution

The small sack-size UPS units are operating at low utilization; this type of unit is very inefficient at low utilization resulting in low energy efficiency. Because of their characteristics and low utilization levels, UPS readout can be inaccurate.

There is very limited electrical backup in Johnston Hall. Since this building operates on a heavily loaded very old electrical system, there is a concern about Business Continuity. For a number of reasons, Johnston Hall is not an ideal space and should not be considered for significant expansion.

5. Efficiently cooled room design

During the summer, heat infiltration from the external wall adds cooling load. While opening the windows can provide emergency cooling, there may be excessive heat gain during the summer, and there is an increased security risk. With no insulation in the interior walls, some heat gain occurs, especially in the winter months.

The equipment layout in the room prevents efficient, effective air flow. Hot spots, with limited air flow are noticeable near some cabinets. Air flow management in the up-flow design (no raised floor) requires appropriate baffles and/or ducts for efficiency.

The large room and equipment layout results in very poor airflow management. With a high level of mixing the CRAC units are very inefficient.

6. Efficient Cooling systems

The old CRAC units are well beyond end of life. The Chilled Water coils are not efficient compared to newer designs. The up-flow units deliver cool air into a ceiling cavity that directs the air down to the return inlet short-circuiting the air flow. The three units provide much more cooling than is needed but their locations make them ineffective.

The Chilled Water supply has control problems. However, the problem is not fully diagnosed. It is possible that the CW supply may be adequate at the level identified for planned use of the room.

Domestic water backup is available at the level needed. More investigation is needed to determine if the sewer drain is adequate for this level. (In the past, the drain could not handle full flow from the 3 units.

Conclusions

Scope of Opportunity for Savings

The current use of ~4,000 MWh annually is a significant University cost (~$400,000.) However, compared to energy retro-fit plans in other areas of the University, the potential savings are not large.

Given that CCS-managed systems account for only 20% of the use, CCS' ability to make significant energy reduction is limited. However, every bit helps so CCS should take the opportunity to reduce costs as it can.

- About 10% of the energy is used by co-located systems. It can be assumed that this is about 50% of the total departmental use across campus. Encouraging departments to buy-

into a hosted virtual server service would give CCS the further opportunity to leverage cost/energy savings. Savings would accrue to the University.
CCS should proactively encourage departments to choose the hosted solution citing sustainability as well as cost as a reason to give up control of their hardware and environment.

- 35% (plus a portion of the cooling) of the energy use is used by SHARCNET. Given research funding, SHARCNET has limited funds to add energy management tools to their system. Since some sectors of the research community are concerned about sustainability, discussions should be initiated to determine if there is opportunity for CCS to extend some of its energy management tools (as it implements them) to the SHARCNET complex. The result would be a more efficient better managed Data Centre.

Physical Resources

In the past because data centre requirements were unique, CCS and Physical Resources (PR) tended to minimize PR involvement in the data centre operation, aside from operational aspects of the CRAC units and CW supply.

With energy management becoming a priority in the University, PR are implementing a Building Automation System (BAS) which can monitor energy use. Adding the facility systems in the Data Centre would permit integrated monitoring, reporting and alarming using standard building system resources.

CCS should develop a working relationship with the BAS (Controls) unit of PR and be early adopters of detailed energy monitoring.

Strategic Plans

The University Data Centre is based on legacy designs and equipment that are not energy efficient. To achieve optimal energy use, the data centre layout and cabinetry must be re-organized and CRAC units replaced with more efficient units. Significant energy savings are possible.

Developing a new model for IT systems design, procurement, and operation will permit continuing improvements to energy efficiency as older systems are replaced and the new model is deployed.

- Evolution to the new model is already in progress with Server Virtualization. Additional energy management tools need to be added to the plan.
  - Using energy conservation as the case, additional funding should be requested to accelerate the Virtualization strategy to achieve efficiencies earlier.
- Desktop virtualization will bring energy economies to user workstations but will result in significant growth in the Data Centre. For 2000 faculty and staff, the current energy budget would be about 40% of current CCS load.
- With virtualization and a hardware strategy, opportunities for high power density design are possible, saving significant space and further reducing energy waste.
- The University must make a significant investment to significantly improve the efficiency of the cooling system.

Funding

Managed by the Energy Conservation Working Group (ECWG) and Physical Resources, the University has an Energy Retrofit program designed to reduce energy consumption. The University receives additional external funding for significant energy savings.

With a goal to tackle "low-hanging fruit", the program annually assesses opportunities for best leverage of the fund. An example is the lighting retro-fit in the Library. Phase 1 is saving **~2,000 MWh** annually. Projects must result in immediate savings.

Short term Data Centre plans, such as virtualization, would be difficult to justify under the Energy Retrofit because the savings are incremental and the savings are difficult to monitor with no energy use monitoring system. Given the scope of CCS-managed systems (580 MWh/year), the energy savings are likely small.

However, Data Centre re-design to a modern energy efficient centre is expensive and could result in significant annual energy savings for the University, depending on project use of the Centre. A comprehensive Data Centre renewal plan could be developed and presented to the ECWG and to University Financial Services to support an augmented capital budget.

The Data Centre of the future?

However, these savings require significant investment to change fundamental designs and supporting facilities. Before embarking on projects of significant cost and effort, a strategic plan for the future of the data centre need to be developed. This Data Centre Strategic Plan would include

- growth of LMS and other academic applications,
- growth of ERP and other administrative applications,
- centre support of IT for research,
- level of desktop virtualization,
- inclusion of systems from existing departmental server room,
- consideration of cloud-based services,
- potential for cooperative shared facilities with neighbouring universities and other public sector institutions.

The plan would identify the anticipated growth of data centre and intended use of the spaces.

Based on this Strategic Plan, a more energy efficient data centre design can be developed.

- Using a rough estimate of doubling compute capacity over 5 years, it is possible to house the data centre *completely* in Room 033A (with the deeper raised floor).
- With appropriate cabinets and room layout (air-managed hot/cold aisles), a virtual server and storage resource support 8 kW cabinets (320 kW = 40 cabinets).
- With more efficient systems, the electrical and CW supply are adequate for a doubling of the load. Improved heat exchange efficiencies can reduce the load on the CUP.

Staffing

Professional and technical skills required to manage a data centre are rapidly increasing because of energy conservation. It is not reasonable to expect that expertise to be held by a small group in CCS.

- A Data Centre Facilities manager, with knowledge of building systems and energy management could provide the bridge between CCS decision making and professional skills acquired elsewhere.
- Alternatives to in-house management an operation exist.
    - Since Physical Resources are expanding their expertise through their Building Automation System (BAS), cooperation between CCS and Physical Resources may be the most effective resourcing strategy.
    - Third-party management firms could manage the data centre facility design and direct local operations staff reducing need for local engineering and management expertise. Targeting a large commercial need for data centre management, these firms tend to be expensive. However, they bring the best expertise to large planning/construction projects.

Outsourcing the entire data centre removes the need to have expert staff and provide continuing professional development and training. Energy load is transferred off-campus. University/CCS would benefit from increased agility from flexible contracts though high reliability services may remain a premium.

An alternative is for nearby institutions to form an operations group that can sustain the appropriate levels of expertise for combined operations. Data Centre operations may or may not be consolidated depending on the business plan.

Operational Improvements

- Accelerate migration to virtual servers to remove older server technology.
- Develop a process to identify and shutdown idle, non-critical components, especially out of business hours. Targeting old non-virtualized servers will achieve the best savings.
- Reduce CRAC unit energy waste by disconnecting re-heaters and by increasing and balancing the set-point temperatures to eliminate the normal operation of the compressors.
- Install curtains to contain air in hot-cold aisles of SHARCNET facility to improve efficiency of XD cooling.
- Where possible, move CCS servers from 033 to 033A to balance heat load.
- Pilot CCS online monitoring of an UPS and a CRAC unit.

Tactical Projects

- Continue Virtualization strategy to improve utilization of servers. Add energy management control software to reduce idle processors.
- Monitoring is the key to energy management.
    - Consider energy monitoring as a requirement for all new server chasses.
    - Replace current Cabinet power-bars with rack PDU’s with built-in monitors.
    - Develop a plan with Physical Resources for active facility monitoring.
- Consolidate new server chassis in a limited area rather than them spreading out. Implement load cost air flow management with curtains and under floor baffles. Reduce the number of active CRAC units, keeping idle units for backup.

Further Investigations

ANS Data Centre

Server computational efficiency / virtualization / power Management

- Assess computational efficiency monitoring
- Review virtualization plans
- Review power management plans
- Interpret as a component of energy conservation. *(Can we point to real energy savings as a fundable conservation measure?)*

IT equipment renewal planning

- Investigate making a case that rapid renewal (greening) is a cost effective conservation measure. *(Some experts suggest 3 yr renewal matches growth in capacity requirements.)*

Energy conservation operating practices

- Consider operating practises, such as shutting down development systems out of business hours.
- Consider server power connection to maximize reliability while reducing energy use.

Johnston Data Centre

Energy conservation operating practices

- Investigate costs of fixing the Chilled Water supply.
- Investigate cost of new CRAC units designed for anticipated load.
- Investigate cost of new room-size dual UPS matching available capacity and anticipated load.

Appendices

Appendix 1	Specific Recommendation Details
Appendix 2	Energy Flow Diagram
Appendix 3	Energy Use Summary
Appendix 4	Facility Capacity Limits
Appendix 5	Cooling System Operating Characteristics
Appendix 6	Energy Use Analysis Summary

Appendix 1 Specific Recommendation Details

ANS Data Centre

1 . Computational efficiency

Ultimately we want to maximize computational efficiency – getting the most value from the computer systems for the least amount of energy. This is achieved through a combination of high utilization of processors, limited powered-on idle time, and choice of power-efficient processors and components. Because requirements, user activity, and improving power efficiency of components is constantly changing, computational efficiency requires regular replacement of older components, specific attention to efficiency during design, and constant monitoring and adjustments during operation. *Combined significant, though individually marginal gains can be made to energy reduction through attention to computational efficiency in the design and operation of our Data Centre IT systems.*

Ensure each project deploying new or upgrading systems address opportunities for marginal improvements in energy efficiency through alternate design, alternative use plans, and higher utilization targets for processors. Ensure application owners are involved. This tactical plan should include

- **Accelerating Virtualization** to improve computational efficiency of the IT systems,
- **More detailed monitoring and measurement of energy use** of these new systems should be implemented to demonstrate energy savings and to better manage the electrical distribution.
- **Review Storage Systems Plan** to look for energy savings options such as tiered storage including power-managed low priority disk for archiving and other in-frequent-access storage. Consider backup storage systems that can be power cycled when not in use.

2. IT equipment renewal planning

- **Replace Components older than 4 years** to avoid power waste from old technology (power efficiency of processors doubles every 4 years).
- **Power Management Controls** in server blades and chasses permit automated control of active server numbers to match demand using software such as VMware's Power management suite.

3. Energy conservation operating practices

- Develop a process to identify and shutdown idle, non-critical components, especially out of business hours. Targeting old non-virtualized servers will achieve the best savings.
- Working with Physical Resources, adjust CRAC units for optimal operation.
  - Increase for higher room temperatures without extreme hot spots.
  - Disconnect re-heater units – they are not needed
  - Balance units for equivalent outflow temperatures
- Pilot UPS and CRAC monitoring instrumentation. Working with Physical Resources, determine whether monitoring should be done by the BAS (Building Automation System) or by CCS Big Brother.

Energy Monitoring and Management

- *You can't manage what you can't see.*

Energy Management must be a key design issue for ALL projects. To identify energy saving opportunities and to demonstrate success, all energy use of all IT systems must be monitored.

Monitoring: Implement an automated energy monitoring system to report IT systems energy consumption (in est. $) and highlight computational efficiency (processor utilization, power-on status, and power consumption) to system designers and application owners. The monitoring system should be able to extend to other IT sites, including major building network closets.

a. A comprehensive plan should include upgrading the cabinet power distribution units (PDUs) with ones capable of line power monitoring and communication.

b. Operating practices should change ASAP to ensure idle equipment is powered down or reverts to a lower power state (Sleep). Initially manual, the activity will demonstrate the value and design of automated solutions.

4. Efficient electrical power delivery and distribution

- The UPS systems are relatively new and efficient so savings are not expected with their redesign. However the battery banks waste energy and create heat. When these batteries reach end-of-life, the battery systems should be reduce to the size required for minimum carryover, given the diesel generator system.
- Better automated monitoring of IT system loads could influence better practices.
  - Automatic data collection UPS loads will be investigated.
  - “per rack” load monitoring should be implemented.

5. Efficiently cooled room design

- Reduce CRAC unit energy waste by disconnecting re-heaters and by increasing and balancing the set-point temperatures to eliminate the normal operation of the compressors.
  - This project should be initiated ASAP by incrementally raising the room temperature so that the re-heaters do not operate. The re-heater fuses should then be removed to prevent their operation.
- Install curtains to contain air in hot-cold aisles of SHARCNET facility to improve efficiency of XD cooling. This should have a significant effect on the room and reduce or eliminate room warming when on Domestic Water.
- The problems in Room 033 can easily be eliminated by transferring IT systems to Room 033A which is under inefficient because of under utilization.
- The most in-efficient part of cooling the large volume of air that is circulated, remixed, and returned to the CRAC units at an only slightly elevated temperature. Efficient room design is expected to provide the most impact on conservation.
- Operating the room at a significantly higher temperature will increase CRAC efficiencies and chilled water conservation. Operating at a higher temperature required efficient air management to avoid hot spots. The investigation will consider how to achieve this.
- **Data Centre Consolidation:** To improve cooling efficiency, IT equipment in the data centre must be relocated to reduce air flow distance from CRAC units.
  - The large room and equipment layout results in very poor airflow management. With a high level of mixing the CRAC units are very inefficient.
  - During the summer, heat infiltration adds cooling load.

6. Efficient Cooling systems

- The chilled-water CRAC units operate very inefficiently. Higher room temperatures, better air management can improve this. Variable speed fans and use of refrigeration boost can also improve efficiencies in parallel with air management.

- The CUP operates the chilled water system at a lower temperature to accommodate the CCS Data Centre lower temperature. Significant cost savings could be achieved by increasing the chilled water supply temperature.
- CRAC #6 already has a network interface. The UPS interfaces are inexpensive. These units can be concurrently linked to the CCS Big Brother monitoring system and to the PR BAS monitoring. Working with PR, CCS should determine whether the BAS reporting provides adequate views of energy use and alarms. When a successful arrangement is proven, the other UPA and CRAC units can be added by purchasing more network interfaces.

Johnston Hall Server Room

1 . Computational efficiency

No recommendations

2. IT equipment renewal planning

No recommendations

3. Energy conservation operating practices

The Johnston Hall Server Room should be included in the energy management monitoring and reporting plans, whether CCS-implemented or by the PR BAS.

4. Efficient electrical power delivery and distribution

- The small sack-size UPS units are operating at low utilization; this type of unit is very inefficient at low utilization resulting in low energy efficiency.
- Replace the small UPS units with a Room UPS.

5. Efficiently cooled room design

- The large room and equipment layout results in very poor airflow management. With a high level of mixing the CRAC units are very inefficient.
- During the summer, heat infiltration adds cooling load.
- Develop a plan to re-organize the IT systems equipment layout into hot-cold aisles with flow through cabinets. Orient for efficient air low to CRAC units.
- Install a well insulated temporary wall to reduce the cooled area to a minimum. (Moving the wall can provide expansion. Insulate the external wall window area.
- **Data Centre Consolidation:** To improve cooling efficiency, IT equipment in the data centre must be relocated to reduce

6. Efficient Cooling systems

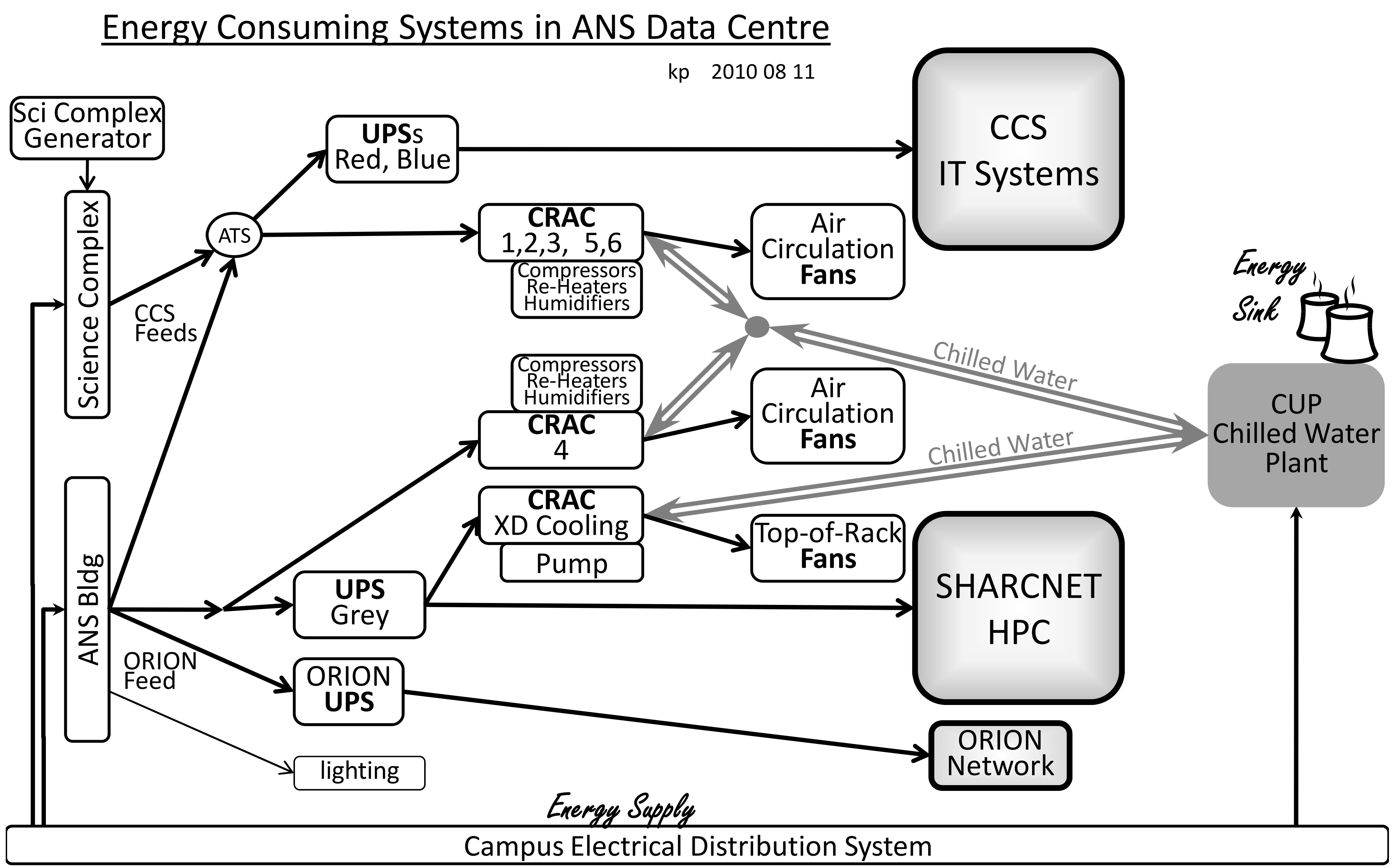
The cooling system in Johnston Hall is a critical risk, given its problems and obsolete CRAC units. However major investment should be avoided until a strategic plan is developed to direct that investment.

- A CRAC unit with a local cooling unit also requires an outdoor condenser; its location in a cool (non-sunny) location may be difficult to find. Physical Resources can provide Chilled Water a lot more inexpensively than using a local refrigeration-type CRAC unit.
  - Determine Chilled Water requirements from Server Room plans.
  - Work with Physical Resources to determine and cost a solution for the supply controls problem.

    - Replace obsolete CRAC units with 2 small Chilled Water up-flow units, for redundancy.
    - Move spare small CRAC unit from ANS (requires raised floor in Johnston to handle down-flow unit).

- **Re-location of CRAC Units** As an immediate tactical plan, consider re-locating an CRAC unit from ANS 033 to Johnston Hall. Specifically, initiate 2 projects.
  - Consider relocating some current IT systems from ANS 033 to 033A to reduce cooling load in 033. Additional re-location remaining equipment may be necessary to optimize air flow patterns.
  - Working with Physical Resources, consider the feasibility of moving one smaller CRAC unit from ANS 033 to Johnston Hall. Determine if the compressor boost capacity of the Liebert CRAC units will provide sufficient cooling on limited domestic water should chilled water be lost.
  - Install temporary wall and increased window insulation to reduce external heat source in the summer. Room layout changes and ducting to improve air flow are required.
  - Consider additional energy management measures, including powering down equipment, and replacing smaller UPSs with larger units operating at higher load levels for efficiency.

Appendix 2 Energy Flow Diagram



Appendix 3 Energy Use Summary

Energy management involves not only the IT systems, but also the electrical power and cooling systems. Data Centre energy consumption involves two components.

Total Energy Consumption		Annual Energy Consumption	Annual Cost
Data Centre	Electricity for IT systems, CRAC units, lighting, and controls.	**2,900 MWh**	**$290,000**
Central Utilities Plant (CUP)	Chilled Water for Cooling *(includes chilling and pumping)*	* **967 MWh**	* **$96,700**

* Applying the Conservation of Energy, the CUP cooling load is equal to the electrical energy consumed. Physical Resources estimates the cost of cooling at about **0.333 kW/kW**. *(An outstanding question is whether this includes pumping and other costs).*

A breakdown of the electricity energy consumption in the ANS Data Centre was determined.

Data Centre Energy	**Consumption(MWh)**		**Cost**
IT systems: CCS	580.0	**20 %**	$ 58,000
	261.0	**9 %**	$ 26,100
SHARCNET	1015.0	**35 %**	$101,500
Electrical Systems *	262.0	**9 %**	$ 26,200
Lighting	14.5	**0.5%**	$ 1,450
Air Circulation	435.0	**15 %**	$ 43,500
Cooling	333.5	**11.5%**	$ 33,350

* The electrical load is primarily energy lost as heat in the UPSs(89%) and the distribution transformers(97%), calculated from efficiency ratings.

Power Utilization Efficiency (PUE)

PUE, the ratio of total energy use to IT systems energy use, is a means of comparing a data centre's energy management design with industry norms or other data centres. Energy conservation projects seek to lower the PUE. Design of efficient data centres aims for a PUE < 1.6.

Based on the above data, the ANS Data Centre has a power utilization efficiency of

PUE = 3,867 MWh / 1,827 MWh = **2.12**

indicating energy use is *reasonably efficient*.

Appendix 4 Facility Capacity Limits

Electrical

Power to the ANS Data Centre is supplied through 4 feeds.

Feed	Systems supplied	Backup	Capacity	Current
CCS	2 CCS UPS CRAC units: 1,2,3,5,6	- Auto switchover from Science Complex to ANS. - Backed up by Science Complex diesel generator.	**~ 350 kW**	~ 170 kW *
SHARCNET	SHARNET UPS CRAC units: 4, XD	From ANS bldg No Backup	**~ 250 kW**	~ 150 kW *
ORION	ORION UPS for Internet connection	From ANS Bldg No Backup	**~ 10 kW**	~ 2 kW .
Lighting	Lighting on its own circuits	033 has some emergency lighting on essential supply	-	-
		Data Centre Total	**510 kW**	**322 kW**

* The CRAC unit loads are periodic depending on cooling requirements. Design loading accounts for all units being on at the same time. Peak current use is the total of the UPS constant loads and all CRAC loads.

From the above data, the ANS Data Centre is operating at **less than 50% of its electrical capacity**. The peak electrical loads of the CRAC units will not increase with increased IT Server load. Available capacity for IT Server and HPC equipment is

- **180 kW**, backed up by diesel generator
- **100 kW**, not backed up

Cooling

The CRAC units rated capacity is noted below. Actual capacity depends also depends on the capacity of the Chilled Water supply; this capacity has not been determined, but is assumed to adequately allow all CRAC units to operate at full capacity.

Room	CRAC units	Cooling Capacity	Current Load
033	1 (15T), 2 (15T), 4 (22T) 15x 8 kW XDV top-of-rack (local)	182 kW 120 kW **282 kW**	**250 kW**
033A	3 (22T), 5 (22T), 6 (30T)	**260 kW**	**100 kW**
	Data Centre Total	**482 kW**	**350 kW**

Because the CRAC units are not operating at efficient temperature ranges, their capacity based on Chilled Water cooling is somewhat diminished. Currently the capacity boost with refrigeration compressors compensates for the inefficiencies resulting in a higher energy cost.

Appendix 5 Cooling System Operating Characteristics

Under-floor Flow CRAC cooling units

The efficiency of the Chilled Water cooling coils depends on the Chilled Water input temperature and the temperature difference between air inflow and outflow.

Air Circulation

A critical part of the cooling process is the room air circulation which transports heat energy from the IT Servers to the CRAC cooling elements. This air circulation is now completely handled by fans in the CRAC units.

Cooling System Inefficiency

Although hard to measure specific energy use, a number of observations point to significant inefficiencies in the Data Centre cooling system. Historically, with a low cost Chilled Water supply, efficiency was not a concern. Now, depending on the current energy cost of Chilled Water, the inefficiencies are wasting a significant amount of energy.

- The room temperature set-points are too low causing cooling boost using compressors. This results in over-cooling compensated by CRAC output re-heaters. This is happening in some but not all CRAC units. The Chilled Water supply alone should be sufficient to provide sufficient cooling.
- Especially in Rm 033A, the CRAC fans circulate air though a large volume without air management design. The warm and cold air are mixed resulting in lower return air temperature. The result is that the CRAC units cool over a small temperature difference, resulting in in-efficient use of Chilled Water.

Appendix 6 Energy Use Analysis Summary

	System	Relative Energy use	Efficiency Concerns	Opportunity for energy savings	Scale of Improvement Cost
1	**IT Systems**				
a)	Design	**CCS: 28. %** **Sharcnet: 35. %** 63. %	Computational efficiency Virtualization Increasing demand: Research, Learning, Business/Administration	Increased Virtualization Power monitoring is key to identifying and demonstrating energy savings.	***Limited savings / Low cost*** Part of good system design – *designing for computational efficiency*
b)	Purchase		**20%** more energy consumed by older(>3 yrs) servers. *(Industry estimate)*	Replace older equipment sooner Select for lower power and better power management. Maximize virtualization of servers	***Growing savings / increased replacement budget*** Renewal plan – budget trade-off: *Faster renewal saves energy!*
c)	Operating		**60%** of the IT Systems load is consumed by idle cycles. *(Industry estimate)*	Energy conservation operating practices Track limited use systems ... Distinguish development systems, etc. Automated monitoring tools Time-of-Use planning and controls????	***Significant savings / Higher cost*** Monitoring energy impact to changes practices Requires cultural changes – users and IT unit
2	**Lighting**				
		0.5%	Old T12 lighting less efficient High lighting level not needed	Replace T12's with T8's Reduce lighting units in 033	***Marginal savings / PR Energy Retro-fit***
3	**Electrical Supply**				
a)	In-room	**10%** Heating from UPS and wiring	Already efficient electrical power delivery and distribution Maintaining 3 phase balance Power factor correction?	Better rack PDUs – measuring power distribution units Active balancing of loads	***Marginal savings / significant cost*** Already efficient but needs monitoring instruments - plan with other facility upgrades.
b)	External Supply	***Beyond Scope***	Cross-campus energy loss	Reduced Data Centre consumption reduces losses proportionately	***Beyond Scope***
4	**Cooling Systems**				
a)	Air Mgmt	**Fans 15%** Air circulation	Constant load regardless of cooling requirement. Poor air management results in moving a lot of air with limited value. Improper mixing reduces cooling efficiency.	Hot/Cold Aisles; better cabinets. Re-organize room to reduce air flow distances; Use curtains and under-floor baffles to direct air; More temperature measuring points; Retrofit variable speed fans,	***Mid level savings / significant costs*** Major project costs to re-organize the Data Centre equipment layout.
b)	In-room CRAC units	**Compres'rs 5%** **Re-heaters 6.5%** **Humidifiers 0%**	CRAC units operating very inefficiently Chilled water alone should be sufficient. Heaters should not be on!!!	Disable Re-heaters Increase room set-point for more efficient CRAC. Link compressors to CW loss operation	***Mid-level savings / significant costs***
c)	Chilled water supply	**CUP energy costs not known**	Data Centre is over-using Chilled Water because of DC in-efficiencies. Low CW temperature not needed.	Higher room temperature set-point. Increase water temp. and differential temp.; monitoring instrumentation needed.	***Impact on CUP Energy use*** Changes involve Physical Resources