HEALTHCARE BUILDINGS – FINANCIAL BENEFITS OF INDEPENDENT CLIENT-SIDE COMMISSIONING

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Note: Due to the intimate nature of the issues detailed in this report, we have the responsibility of protecting the anonymity of the hospitals involved. The owners of the different confidential hospital projects mentioned in this whitepaper will all be referred to as 'Client' throughout. The identification of the different hospitals across the GCC will also be protected, and they will be identified by numbers instead, i.e. Hospital 1, 2, and so on.

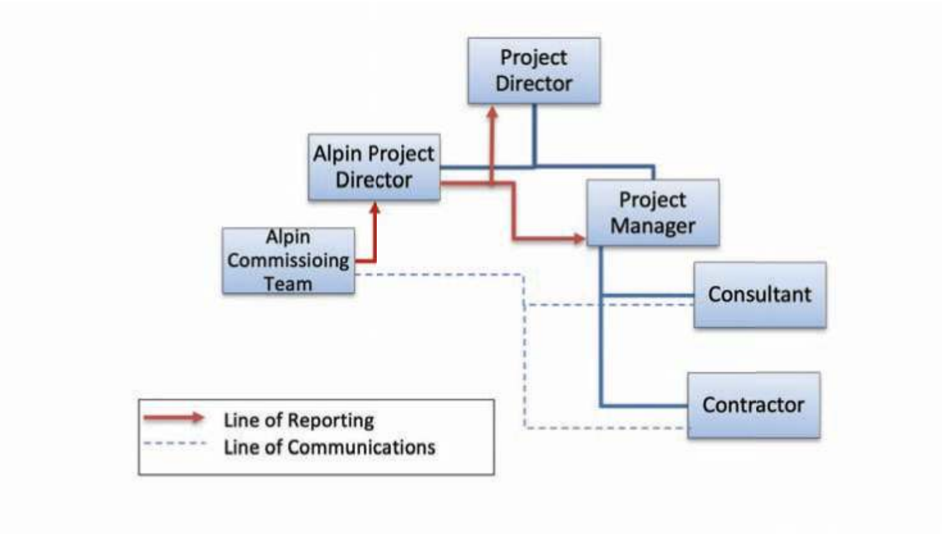
Executive Summary

This report has been developed to demonstrate the financial benefits of the Independent Commissioning Auditor and Advisory role, and has been prepared specifically for eight confidential hospitals in the GCC. On each project, Alpin studied various commissioning aspects and activities from the Design stage to Construction and through to Operations, and highlighted the financial benefits that could be achieved through water and energy savings.

It is worth noting that:

- Alpin Technical Auditors (all ASHRAE certified commissioning auditors) followed ASHRAE standards, as did some of the team that are certified under the ASHRAE Healthcare Facility Design Professional Certification (HFDP).

- Alpin Commissioning Auditors reported directly to the Clients, as shown in the following communication chart.



Below, we provide a summary of the financial benefits of Commissioning as it pertains to this case:

1. In addition to design and construction technical audits, the Alpin Commissioning team also verified the seasonal testing (post-handing over) during the normal operations phase of the hospitals, during which the projects consultant and contractor would not be available. Our role was to ensure that all systems were performing efficiently and to ensure the ongoing optimized performance of buildings (to save energy and water). Alpin then reported these findings directly to the Client(s) and explained that 15-20% of the overall power and water consumption could be saved.
2. Testing, Adjusting and Balancing (TAB): It was noted that in several hospitals the TAB was canceled as part of a value engineering exercise; Alpin raised an issue to the Client(s) to reconsider this aspect. We provided our recommendations based on the energy analysis which showed that eliminating the TAB services may lead to an increase in power consumption by 12%. We also found that the electrical power

supply bill would increase by AED 339,833.15 each year per hospital, and the total loss for the eight hospitals was expected to be around AED 2,700,000.

3. Sanitary Fixtures - Water Flow: We also recommended using water saving fixtures. Based on our recommendation each hospital would be able to save AED 507,500/ year on its water bill. When these savings are applied as an average across the eight hospitals, the total savings were estimated at AED 4,000,000/year.
4. Reverse Osmosis (RO) System: One of our other recommendations was to reuse the RO water discharge in the irrigation system and WC flushing; the total water savings for the eight hospitals were then calculated to be AED 1,000,000 AED/year.
5. During the design reviews that we performed, one of our recommendations was to provide an efficient chilled water system to save energy consumption in the chilled water pumps and chillers. For example, for Hospital 8, we calculated that the energy savings would be about 15% of the total consumption, which would save AED 316,240/year for one hospital; if we applied these savings to the hospital branches 1, 2, and 6, the total savings would be AED 945,000/year for the four hospitals combined.
6. The below schedule summarizes the above mentioned savings:

Saving	AED/year	Remark
Seasonal tests and Post Occupancy Cx activities		15-20% of the utilities bill
TAB	2,700,000	TAB to be hired – by the contractor, for all hospitals
Sanitary Fixtures Water Flow	4,000,000	LEED water flow requirement to be considered by contractors
Reverse Osmosis rejected water	1,000,000	Contractors to reuse discharged water for all hospitals
Chilled water system	945,000	For Hospitals 1, 2, and 6

Below are some of the serious observations reported by Alpin's Independent Technical Auditors, which had not been reported previously by the project consultants:

1. Chiller foundations (Hospitals 2 and 6): During our site observations, we reported a serious issue with the chiller foundation fabrication and installation that would lead to shutting down the chilled water systems in the hospital, which would in turn impact the hospital operation (including related critical life and safety functions); the estimated impact of this issue would be the complete shutdown of the hospital for at least 3 weeks, while the overall impact to business and reputation of any life-safety equipment would be disastrous and would require extensive estimation on an overall corporate level.
2. Installation of Fire Dampers: We observed and reported improper installation of fire dampers in Hospital 5; we raised the concern that if this was not rectified it would cause both risk to life, as well as financial losses related to operational shutdowns.
3. Fire Risers: In Hospital 5 we noticed that the entire pipe riser lacked any structural support. In addition, the top section of the riser pipe coupling was loose, which would lead to serious damage in the fire fighting system.
4. Location of Fire Pumps: In Hospital 5, the fire pumps were located on the roof, and for protection measures the contractor had provided a shed over the pumps. We raised this as an issue, and the contractor extended the shed; however, the extension did not fully protect the fire pump component. In addition, we raised an issue about the filling of the diesel tank located on the roof; at the time, the filling of

the diesel tank was done by carrying diesel containers through the building elevators. Such a shortcoming from the designer was unexpected, (we were engaged only during the construction phase, as opposed to the design phase of this hospital) especially that they did not consider this issue that would seriously impact the fire safety of the building.

5. The following table shows some of the issues we reported in Hospitals 4 and 8 design reviews:

Item	Short Description
Missing Emergency Lights	Emergency lighting not provided in some areas. The Commissioning review helped to discover this in the early stage of the design. It impacts life safety and having to upgrade the system causes a financial impact as well.
Missing Sequence of Operations	Proper sequence of operations of all major equipment will help to save energy, provide proper operation of the facility, and provide comfort for the occupants. Commissioning reviews will cover this to make sure that the sequence of operations is good enough to meet the facility requirements.
Sump Pump Emergency Operations	The Commissioning review revealed that sump pumps were not fed from the emergency power supply. Healthcare facilities should be designed to operate even in the event of a community disaster. If this strategy is not considered, it may face issues in the authority/JCA approval process as well as other associated project delays.
Missing Equipment Schedules	The Commissioning review revealed that the designer did not provide any equipment schedules. Equipment schedules help ensure that energy efficient equipment are selected, and the capacity of the machines match the requirements of the facility. Efficient equipment will help save operational costs. At the same time, avoiding oversized equipment will reduce the initial costs as well as running costs. Moreover, avoiding undersized equipment will help eliminate change orders.
Missing Data of Plumbing Fixture Flow Rates	Fixture flow rates should be in compliance with the project requirements. Flow rates above the required limits will result in water and energy wastage (from water heating) which will elevate operational costs.
Cross Contamination Issues and Coordination	1- For Anti Room and Isolation rooms, please indicate pressure in reference to each surrounding space (positive/negative.) (Provide similar information for any room with special pressure requirements.) 2- It is recommended to have the above mentioned rooms in a separate detailed drawing due to the critical nature of such rooms 3- The ventilation drawings should also show the fresh air provided for each space (not just Exhaust air). This facility should be 100% Exhaust air (no re-circulation is allowed). 4- Please clarify what kind of ventilation (Exhaust) is provided for the electric and telephone rooms. 5- Since this project is a healthcare facility, it is highly recommended to have no air circulation whatsoever between spaces, to avoid the spreading of infectious diseases and hazardous air contaminants (even if ultraviolet filters are provided).
Issue of Water Efficiency	1- Please avoid running potable water pipes through electric rooms between grid E, C/ 12, 13 so as to avoid electrical shock hazards. 2- Please ensure provision of low-flow plumbing fixtures in line with the project's adopted sustainability standard. Fixtures schedule to be provided.
Issue of Clarity in Design Drawings	1- For all spaces protected with FM 200 (or any clean agent) the room shall undergo an Integrity test conducted by a specialized third party. 2- We are expecting complete room details along with locations for FM 200 cylinders.

Item	Short Description
Issues of Missing Design Elements, Lack of Design Clarity, and Accessibility and Maintenance	1- Please provide return diffusers to HK room. 2- Room 04-02-004 has two FCUs in the same patient bathroom. Noise levels will be very high, and the room would be very congested with services which will make it difficult to maintain. 3- Please provide supply and return air to room 04-09-030 - Medication room. 4- Please provide return air to DU room. 5- Please provide return air to room 04-09-039. 6- Please provide supply and return air to HK04-09-038. 7- Provide ventilation to change room. 8- Has the CO2 demand ventilation been considered? Please ensure ASHRAE standard 62.1 will be implemented in this project. 9- All WCs served with only mechanical ventilation with no fresh air supply. 10- Please provide 60 x 60 access door to all VAVs for proper future maintenance.

The Financial Benefits of Commissioning

TESTING, ADJUSTING AND BALANCING (TAB):

During the Value Engineering process, a decision was made to eliminate TAB tasks from one of the contractors' scope of work.

- As the Commissioning Advisor, Alpin recommended a TAB contractor to be hired to perform Testing, Adjusting, and Air Balancing for the systems to be commissioned, particularly for the Air Conditioning System (HVAC). An unbalanced HVAC system will lead to air infiltration, increased humidity, mold growth (destroying built asset values and increasing operational repair costs), and increased HVAC power consumption.
- The air infiltration into a building is similar to the effect of additional ventilation. Unlike ventilation, it cannot be controlled. As such, we seek to eliminate undue air infiltration/exfiltration, and to have the HVAC system moderate the fresh air input.
- To prevent infiltration, the building must be under positive pressure. Positive pressure cannot be achieved without balancing the HVAC systems as per the design requirements. For more details as described by one of the industry leaders, please refer to the "Closing Thoughts" section on page 7 of this link.
- Hospital 5 Case Study
    - By running the energy modeling simulation software, we found that the pressurization of the building limits the effects of infiltration and reduces the air conditioning system's electricity bill by 20%. In general, 60% of the electrical power supply cost comes from the air conditioning system. As a conclusion, not conducting the TAB services may lead to an increase in power consumption by an estimated 12%.
        - We assumed infiltration without TAB and pressurization to be = 17.86 m3/h/m2 at 50 Pa
        - We assumed infiltration with TAB and pressurization to be = 10 m3/h/m2 at 50 Pa (UAE maximum allowed rate)
- Financial Analysis:
    - In the case of Hospital 4 where the total connected load is 747 KW with a Diversity Factor of 90%, and the fact that eliminating the TAB services may lead to an increase in power combustion by 12%, we found that the electrical power supply bill would increase by AED 339,833.15/year per hospital, bringing the total loss for the eight hospitals to AED 2,718,665.16/year.

SANITARY FIXTURES WATER FLOW

- For Hospital 5; we discovered that the washbasin taps' water flow was 22 liters/minute, which is almost ten times that of the required water flow for public taps; e.g. 1.9 liters/minutes is the standard LEED requirement.

- As agreed with the Client's project team, the contractor was to regulate the water flow rate for medical staff washbasin taps to 2.8L/m and for the other fixtures to 3.8 L/m.
- At Hospital 5, there are 46 taps for the medical staff and 114 others.
- Financial Analysis:
  - We conservatively assumed that each one of the washbasin taps would be used only for a period of one minute per use, four times each hour between 8:00 am to midnight (for 16 hours a day). However, we believed the actual usage would be higher than our conservative estimate.
  - The savings in water consumption would be 53,199 Omani Rial/year (AED 507,500); for the two hospitals it would be AED 1,015,000/year.

REVERSE OSMOSIS (RO) SYSTEM

- Taking the average of 5,000 gallons/day capacity of the RO system across the hospitals, to produce the 5000 Gal/day, the system needed to consume 12,500 gallons/day.
- 7,500 gallons of this goes to the drainage system. Rather than taking this amount to the drainage system, we recommended that this amount be used for irrigation and WC flushing.
- Financial Analysis:
  - In a year, 2,737,500 gallons of water would go to the drainage system.
  - The savings in water consumption would be AED 145,278/year (based on DEWA's online calculator) for each hospital, and the total savings for the six hospitals would be AED 871,668/year.
  - The total savings from this recommendation is AED 1,054,466 AED/year.

CHILLED WATER SYSTEM DESIGN

- We noticed that in some hospitals, e.g., 2 and 6, outdated chilled water equipment were considered in the design. The chilled water system for Hospital 6 used constant-speed chilled water pumps. As a common practice, we recommended in our design reviews to consider primary and secondary chilled water pump circuits:
  - Constant primary & variable secondary
  - Variable primary
- The following links from Trane Engineering News Letter in 1999 and ASHRAE Journal in 2002 show that since the early 21st century, professionals have advised using the aforementioned kind of chilled water systems, to replace the basic ones that were used in the mentioned hospitals. Today, designers have the tendency to minimize the value of using such systems and are not aware of the benefits they bring to the table; for example, the constant pumps and chillers both operate at a constant speed whatever the demand is, whereas variable systems modulate the speed of pumps and chiller compressors based on the actual demand, which leads to a decrease in the power consumption of the chilled water system.
- According to HPAC Engineering Magazine November 2011, "of the three basic piping configurations, VPF has the greatest potential for energy savings because of the inherent efficiencies of variable-speed pumping."
- This snapshot from the US International Congress of Refrigeration in 2003 shows the potential savings on a project using more innovative and adaptable systems.

- It should be noted that the above-mentioned issue, in addition to other energy-related comments concerning the variable-speed AHUs and VAVs, were not rectified according to our comments.
- Financial Analysis:
  - In Hospital 8, for example, we calculated the savings to be about 15% which would save AED 316,240/year in one hospital; if we applied these savings on the 1, 2 and 6 branches, the total savings would be AED 984,720/year for the four hospitals.

CHILLERS FOUNDATION

The Chiller Floating Slabs at Hospitals 2 and 6:

- A Chiller Floating Slab is a concrete slab over layers of rubber on the roof slab. The edges of the floating slab must be properly treated to prevent water leakage under the floating slab and leakage through the roof slab inside the building. The floating slab prevents the chiller's vibration from transmitting to the building.
- The top-level of any floating slab must be higher than the roof level.
- At Hospital 2, the floating slab level was lower than the roof level, by around 15 centimeters. In case of rainwater drain blockage, rainwater would accumulate and leak under the floating slab, and with time, water would leak inside the building. Therefore, we asked the civil engineer to provide a solution to solve this issue.
- It should be noted that this issue is related to the building envelope and was not under Alpin's scope. We reported this to mitigate the enormous impact it would have had on the hospital operations in case of a water leakage inside the building.
- Financial Analysis:
  - We left it to the Client(s) to estimate the cost of closing the hospital for at least 3 weeks, should operational stage repairs be necessary.

FIRE DAMPERS LOCATIONS

- According to the NFPA and local civil defense codes, it is required to install a Fire Damper (FD) for all ducts passing through a fire zone. This is to prevent the fire from spreading through the air duct to adjacent areas.
- An FD was to be fixed inside the wall, sealed with fire-rated materials.
- For Hospital 5, we found that all fire dampers were located around 15 centimeters away from the wall. Due to this, technically, the installed fire dampers would not function during a fire incident; fire would spread to the adjacent areas through the ducts.
- Financial Analysis: Fire would spread through the hospital which would enormously increase the death casualty and financial losses overall.

Appendix A: Case Studies From Other Hospitals

THE VALUE AND ROI OF BUILDING COMMISSIONING: VALUE, COST, AND RETURN ON INVESTMENT

ABSTRACT

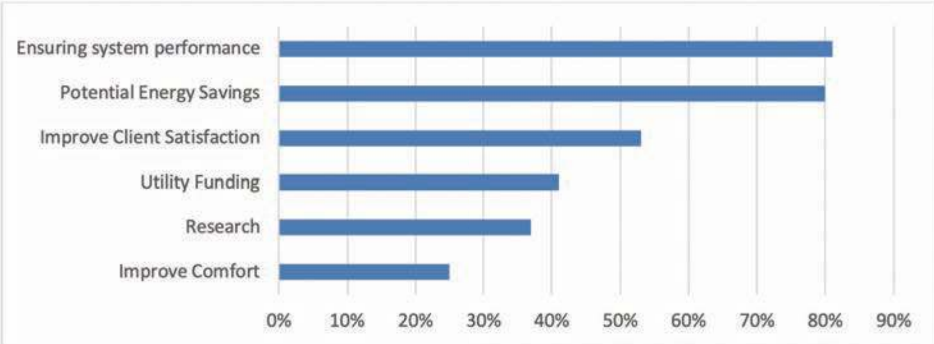
ABSTRACT: Building Commissioning and MEP Audits can bring significant benefits at a relatively negligible cost. The median normalized cost to deliver commissioning is merely 0.4% of the overall construction cost. According to the BCxA, the average surveyed organization achieved energy savings between 5 and 20% within a simple payback period of 1 to 5 years.

BENEFITS OF COMMISSIONING[1,2]

- Ensures proper MEP performance
- Improves building occupant productivity
- Lowers utility bills through energy savings
- Enhances environmental conditions
- Improves system and equipment function
- Lowers maintenance costs due to properly operating MEP equipment
- Results in better building documentation
- Shortens occupancy transition period
- Creates a significant extension of equipment/systems life cycle

WHY OWNERS COMMISSION THEIR BUILDINGS[16]

- The following table showcases the main reasons why owners Commission buildings:



- As building and (especially) MEP systems get more complex, the assurance of quality provided by the commissioning process becomes even more important. This is especially true for buildings with a high expectation for control and performance, like pharmaceutical manufacturing, academic laboratories, or the healthcare industry.[3]

WHEN TO COMMISSION?

Smart building owners integrate commissioning into the building of projects to keep costs in line, meet design intent and operational needs, and improve efficiency.[3]

Good	Better	Best
Commission during: Near the end of Construction	Commission during: Beginning of Construction	Commission during: Design Phase
Test systems for performance and efficiency	Monitor and review construction and systems installation	Help owner formulate project requirements
Ongoing review for completed and occupied building	Monitor and test systems throughout construction phase	Review design and engineering plans
	Final performance and efficiency tests	Monitor and review construction and systems installation
	Ongoing monitoring and reviews for completed and occupied building	Monitor and test systems throughout construction phase
		Final performance and efficiency tests; train building staff
		Ongoing monitoring and reviews for completed and occupied building

COST OF NEW CONSTRUCTION COMMISSIONING

The costs associated with the commissioning process are immediately and continuously offset by staggering saving opportunities related to[4]:

- Improved Efficiency
- Reduced Change Orders
- Improved Maintainability
- Improved Occupant Comfort and Productivity

CONSTRUCTION TIME

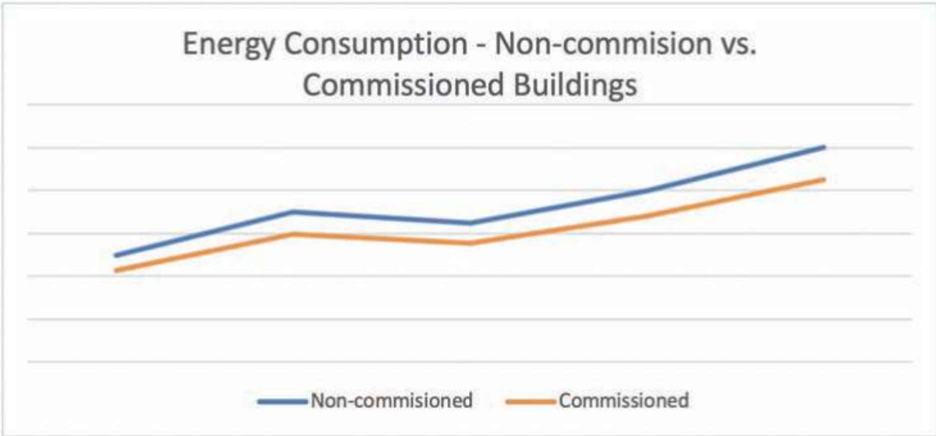
- New Construction Commissioning benefits include a strong ability to drive the level of completeness in building construction, which results in meeting aggressive schedules, addressing construction issues ahead, better design and construction team coordination, and reducing warranty call-backs.[4]
- In 2017, a survey administered by Keithly Barber Associates, a Washington state-based commissioning services firm, found that 80% of respondents believe that commissioning has had a positive impact on building delivery.[5]
- One of the more commonly acknowledged benefits of commissioning (especially design phase commissioning) is that the process will reduce the number of change-orders encountered in a typical construction cycle.[9]
- According to the US Department of General Administration, the best results are consistently achieved when the commissioning process starts as early as the schematic design phase.[6]
- The US Department of Enterprise services states that:
  "Early involvement by the commissioning agent may not carry a cost premium. It will reduce project design problems and will introduce building commissioning expectations early."[8]

OPERATING AND MAINTENANCE COSTS

- Multiple industry sources indicate that on average the operating costs of a commissioned building range from 8% to 20% below that of a non-commissioned building.[1]
- Many commissioning related improvements simply make the systems and equipment in a building easier to service and maintain. Studies show that an early design phase commissioning finding that makes an equipment room easily accessible for equipment replacement can easily save tens of thousands of dollars any time the machinery in the room undergoes a major repair or replacement. This usually happens once per year.[9]
- The burden of unresolved issues will fall on the shoulders of the operating staff as well as severely impact their overall efficiency. Commission costs, although significant, are dwarfed by future functional operating expenses from a Life Cycle Cost perspective.[10]

ENERGY SAVINGS - ELECTRICITY IS THE LARGEST ENERGY USER IN HOSPITALS[11]

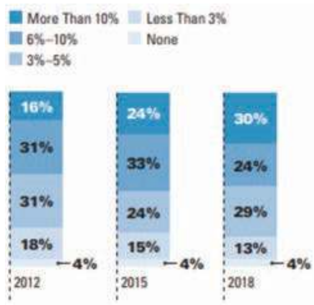
- A study from 2009 by Evan Mills estimated median whole-building energy savings of 16% for existing buildings and 13% for new constructions. Fuel savings for existing buildings were similar, while those for saving centrally generated thermal energy were significantly higher (31%).[12]



- The study of 186 buildings conducted by Evan Mills showed median energy savings in the range of 10 – 15%.[13]
- Cost of Avoided Carbon: If the value is less than zero or less than the cost of purchasing emissions offsets in the marketplace, then the project can be deemed cost-effective. The same study found that the median costs of avoided carbon were -$110/tonne for existing buildings and -$25/tonne for new constructions.[12]

THE VALUE OF COMMISSIONING AND GREEN BUILDING CERTIFICATION

- Reports suggest that the investment in Green Building is increasingly believed to improve Asset Value by more than 10%.[14]
- LEED buildings (and by extension, properly commissioned buildings) have reported almost 20 percent lower maintenance costs than typical commercial buildings, and green building retrofits typically decrease operation costs by almost 10 percent in just one year.[15]



- Non-energy impacts like first cost-savings, improved indoor environmental quality, and reduced risk of construction-defects litigation are of value to virtually every stakeholder in the construction and facility management industry. Unfortunately, these additional benefits of commissioning are hard to quantify and not effectively communicated today.[6]
- Typical Cost Savings per Building Type/Usage.[16]

Building Type	Cx Cost	Annual Savings	Simple Payback (yrs.)
Facility Offices High	$24,000	$89,760	0.3
Rise Buildings Medical	$12,745	$8,150	1.6
Institutions Retail	$24,770	$65,535	0.4
	$12,800	$8,050	1.6

*Average Commissioning costs and savings along with payback based upon the most commonly Commissioned building types.

- The true dollar value of commissioning is not represented purely by first cost value, but also by future cost impact, which can be staggering.[17]

CASE STUDIES

1. Acute-Care Hospital in Minnesota (600,000 sf)[18]
    - 14 recommissioning measures were implemented.
    - The total cost of the project was roughly $208,000 or $0.35/sf.
    - The savings from measures implemented during the project are $181,000/yr, giving a payback of 1.2 years on total project cost.
2. The Shriners Hospital located in California (300,000 sf)[19]
    - 68 separate findings were identified during the retro commissioning process.
    - 19 of the 29 measures were identified as low-cost. Their implementation equated to around $53,500 in utility cost savings. The cost to implement these 19 findings was estimated at $29,600. This represented a simple payback of 0.55 years.
    - The implementation of the other 10 capital-intensive measures equated to savings in excess of $125,000 in annual utility costs or 14.7%. The cost to implement these measures was estimated at $234,000, assuming all materials and most labor is outsourced. This equated to a simple payback of 1.9 years.
    - The savings from changes made as a result of the retro commissioning study will continue to benefit the facility for years to come; annualized savings are approximately $152,000.
3. University of California, San Francisco – Rock Hall (176,000 sf)[20]
    - Implemented an extension to the campus monitoring system by adding new monitoring points, and putting in higher quality sensors.
    - Energy Cost Savings (at representative utility rates): $149,000/year (Roughly 14%).
    - The total cost of $270,000 USD and 1.8 years simple payback period was calculated.
4. Cone Health System – North Tower (240,000 sf)[21]
    - Cone chose to deploy an active chilled beam distributed cooling system in patient rooms, the first such use of this technology in the United States.
    - Operational since 2014, the 96-bed project is performing precisely as predicted, saving 40% in energy costs over a traditional variable volume reheat system.
5. Cleveland Clinic - Twinsburg family health and surgery center (190,000 ft)[21]

- The building was designed utilizing U.S. Green Building Council (USGBC) standards and was certified LEED Gold.
- The most impactful strategies from the commissioning project included: Optimizing air change rates, Maintaining and optimizing air filters, Rooftop Unit (RTU) optimization.
- The project achieved 36% energy savings and $246,000 in cost savings.

6. Banner Bank – Idaho, US (180,000 sf)[23]
    - The Banner Bank Building is a model for high performance buildings in the US.
    - The project worth $23,000,000 USD considered commissioning from the very start.
    - The building performs 30% - 60% better in terms of energy and operating expenses compared to the standard.
    - Up Front Capital Savings. Open floor plans, good envelope design, and load reductions in heating, cooling and ventilating allowed designers to downsize the mechanical systems, reducing equipment cost, installation cost, and structural cost.
    - The developer indicated that the 0.05% of the project budget spent for 3rd party commissioning was well worth the investment. Specifically, systems were balanced, controls and operating sequences were tweaked, extra ceiling return diffusers were recommended and additional training on operating the lighting system helped to realize the energy savings potential in the design.

7. Swedish Hospital – Issaquah, Washington (585,000 sf)[24]
    - It was the first new Greenfield hospital project in King County in 25 years.
    - Swedish executives set the target energy use for the new facility at 150 KBTU/SF/YR, a very aggressive goal considering most hospitals use 230 KBTU/SF/YR.
    - Architects and designers met with staff to design the facility and plan energy savings based on usage patterns and service needs.
    - PSE-funded, third party commissioning that executed careful planning, validated systems, and ensured energy savings were accurate—helping to ease operations from the start.
    - The hospital is now saving $600,000 a year in energy costs alone.

8. Baruch College – New Building Commissioning – Lower Manhattan (780,000 sf)[25]
    - The goal of Commissioning was to ensure adequate system performance and provide thermal comfort to occupants.
    - Secondary goals were to produce energy savings and improve indoor environmental quality.
    - Commissioning was planned and budgeted during the design phase. Commissioning meetings were held regularly and participants were encouraged to actively participate.
    - Result: The Commissioning process helped facilitate communication among the control contractor, mechanical contractor, owner, and designer, helping minimize system shutdowns, additional construction costs, and control sequence complexity.

9. CALTRANS District 3 Headquarters – California (230,000 sf)
    - Commissioning (Cx) was part of a larger Cx Cost-Benefit study for the California Energy Commission.
    - Early involvement by Cx team provided valuable design review input and established relationships with the project team - from planning to occupancy.
    - .Cx cost for the project was $0.59/sf.
    - The study identified the following avoided up-front and future costs related to issues identified early through Cx:
        - $101,432 ($0.44/sf) in avoided first costs.
        - $39,912 ($0.17/sf) in avoided future one-time costs.
        - $105,491 ($0.46/sf) in avoided future annual costs.

10. Montana State Men's Prison at Deer Lodge, Montana (23,000 sf)[26]
    - The project consisted of a two-story addition of 13,000 square feet to the existing two-story building.
    - A $3 million remodeling/addition project included $24,000 for commissioning.
    - The commissioning process found 46 discrepancies.
    - It was estimated that correction of these discrepancies avoided potential damage to equipment and operations and maintenance staff time amounting to $18,540.

11. Community Colleges of Spokane (56,560 sf)[27]
    - Extensive remodel of existing building, plus a 2-story addition to the building.
    - Total Commissioning Cost: $82,820 (1.2% of total construction cost).
    - $10,500 in first-year cost benefits (such as fewer contractor call-backs, reduced change orders, problems corrected at design stage, etc.).
    - $8,100 in annual energy savings.

12. Bainbridge Island High School Addition[28]
    - Update of their 133,000-square-foot high school and addition of 31 classrooms and a new gymnasium.
    - They identified more than 100 significant issues during construction
    - Commissioning cost: $41,860.
    - There were non-energy first-year savings of about $25,000 due to fewer contractor call backs, improved indoor air quality and training of operators.
    - Annual energy savings: $19,450.

13. Northwest Museum of Arts and Culture (84,830 sf)[29]
    - Renovation of existing building, plus new "east building" addition.
    - Total Commissioning Cost: $98,840 (0.6% of total construction cost).
    - $15,800 in first-year cost benefits (such as fewer contractor call-backs, reduced change orders, problems corrected at design stage, etc.).
    - $12,100 in estimated annual energy savings.

14. Kern High School District[30]

- Construction of the new 200,000 square foot Liberty High School campus.

Commissioning Scope of Services	Cost
Entire Building (HVAC, Controls, Electrical, Mechanical)	0.5%-1.5% of total building construction cost
HVAC and Automated Control System	1.5% (over 40,000 ft2) to 2.5% (20,000 ft2 - 40,000 ft2) of total mechanical systems cost
Electrical Systems	1.0%-1.5% of electrical system cost
Energy Efficiency Measures	\$0.23-\$0.28 per square foot

- The commissioning budget was set at $40,000 of the total construction budget of $28 Million. (0,14%).
- The net result was a 75% reduction in contractor call-backs after the turnover of the new facility.
- This reduction also resulted in significant labor and maintenance budget savings for the district.

15. Boise State University Student Recreation Center[31]

- Two story, 90,000 square foot building.
- Commissioning began late in the project, during the construction phase.
- Commissioning cost: $40,280.
- First-year cost benefit: $20,000.
- Annual energy savings: $11,050.

16. Ada County Courthouse. Boise, ID[32]

- Construction on a new 330,000-square-foot facility.
- The County decided to commission the project late in the design phase.
- Commissioning cost: $220,000.
- First-year cost benefit: $106,590.
- Annual energy savings: $25,500.

17. Marion County Courthouse Square[33]

- A new five-story brick building contains nearly 160,000.
- Commissioning cost: $60,900.
- First-year cost benefit: $17,300.
- Annual energy savings: $8,780.

18. North Clackamas High School[34]

- The new school is 250,000 square feet on 42 acres and was built to serve 1,850 students.

- Commissioning cost: $85,000.
- First-year cost benefit: $27,000.
- Annual energy savings: $13,700.

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