PUBLIC

REPORT TO

CORPORATE AFFAIRS, STRATEGIC PLANNING AND PROPERTY COMMITTEE

COST/BENEFITS OF FULL AIR CONDITIONING VERSUS DISPLACEMENT AIR/HEATING IN NEW ELEMENTARY SCHOOLS

"I can do all this through Him who gives me strength."
Philippians 4:13 (NIV)

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RECOMMENDATION REPORT

Vision:
At Toronto Catholic we transform the world through witness, faith, innovation and action.

Mission:
The Toronto Catholic District School Board is an inclusive learning community rooted in the love of Christ. We educate students to grow in grace and knowledge and to lead lives of faith, hope and charity.

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A. EXECUTIVE SUMMARY

Displacement ventilation (DV) and radiant in-floor heating is recommended in the 2015 Elementary School Design Standards report, as an energy efficient alternative for new elementary schools when compared to the more traditional mechanical systems with perimeter heating, (wall fins located along window walls) with air conditioned central plant systems.

In addition to energy savings, DV provides 100% tempered (or treated) fresh air into classrooms, throughout the school year, both in heating and cooling seasons. Cool air is suppled at a low volume from wall grilles located close to the floor level, and as the air travels across the room, it begins to warm, picking up heat from room occupants, equipment and the heated floor. As the air warms, it rises taking with it the stale, contaminated air, which is exhausted at the ceiling level. The fresh supply air is de-humidified, hence contributing to occupant comfort levels during warmer weather.

The 2015 Elementary Design Standards further includes provision for several air conditioned cooling centres within the building; the learning commons, the multi-purpose room, as well as the administration area. Gymnasiums are equipped with air handling units, which provide heating and ventilation, sufficient for everyday school activities.

Various factors should be considered as part of a cost/benefit analysis of DV with radiant in-floor heating verses full AC, with perimeter heat and traditional air handling units with ceiling ducts – capital costs as well as the size and optimum location of the mechanical equipment (outdoors or contained within the building), operating and maintenance requirements, service life, occupant comfort, indoor air quality and energy efficiency.

B. PURPOSE

1. In response to Trustee motion, that approval of the 2015 Elementary School Design Standards, presented at the April 2015 Corporate Affairs, Strategic Planning and Property Committee meeting, *be deferred pending further information regarding cost-benefit analysis of installing a full air-conditioned system verses the recommended radiant heat floor/displacement air system in new elementary schools*.

2. Approval of the 2015 Elementary School Design Standards, as attached in Appendix A.

C. BACKGROUND

1. The Ontario Building Code requires mechanical ventilation in new buildings, additions and major retrofits, regardless of whether there are operable windows in the rooms. Mechanical ventilation is required during the colder weather as an alternative to leaving windows open. On average 75% to 80% of the school days fall within cold weather days, including parts of October and May.

2. Traditionally, in schools equipped with central plant AC systems, air is supplied to the spaces within the building from ceiling diffusers at a relatively high velocity. This is done to ensure that the tempered supply air thoroughly mixes with the warmer room air to achieve a comfortable space. Room contaminants are generally diluted as air is supplied – mixed – returned back to the air handler. In cooling mode, the supply air temperature leaving the diffusers is approximately 13°C. Appendix B provides a photo illustrating the difference between the DV and the traditional mixed air supply.

3. Displacement ventilation provides tempered or treated cool air, which enters the classroom from diffusers or grilles, placed close to the floor. This air is introduced at a low volume (or velocity) and it is treated to remove humidity. The cool air then begins to warm, acquiring heat from room occupants, equipment and the radiant in-floor heating. As it warms, it rises taking with it the contaminants in the air. This air is exhausted from the room. "This vertical airflow pattern near each occupant, often referred to as a thermal plume, makes it less likely for germs to spread".[1] In contrast, typical air distribution systems supply air conditioned air from ceiling outlets at relatively high velocity. This air distribution system causes contaminated room air to mix with supply air as illustrated in Appendix B-1 and B-2.

4. The majority of the Board's elementary schools have limited mechanical ventilation and no air conditioning. The majority of Secondary Schools have full or partial AC systems. The Board has 13 elementary schools with full air conditioning systems as noted in the Table below;

[1] Energy Design Resources, Design Brief, Displacement Ventilation, http://energydesignresources.com/resources/publications/design-briefs/design-brief-displacement-ventilation.aspx

	Elementary School with Perimeter Heat & Full AC	Bldg Age/Years
1	Immaculate Conception	11
2	Our Lady of Fatima	10
3	Our Lady of Lourdes	10
4	Our Lady of Sorrows, (with addition in 2015)	13
5	Our Lady of Victory	11
6	St Anthony	10
7	St Jane Frances (Additions 1967 & 2004)	51
8	St Timothy	10
9	St Robert	12
10	St Helen	22
11	St Luke	38
12	All Saints (with addition in 2014)	12
13	St Nicholas of Bari (with addition in 2003)	39

5. The six new elementary schools (St Nicholas, St Conrad, St Ambrose, St Edward, Blessed Pier Giorgio Frassati and St Andre) recently completed under the Board's Phase 2 Capital Program have the DV with radiant in-floor heating throughout the building. Optimal indoor air temperature can be achieved with Displacement Ventilation for the majority of the shoulder season. Data from Environment Canada for the past three years indicates that there are on average 20 to 35 "hot degree" days per year in Toronto during the summer months, where the exterior air temperature is at or above 30°C. The table below provides comparative temperature readings for three similarly sized of elementary schools, taken in an occupied classroom on a hot degree day:

A. SCHOOL	The Divine Infant	St Conrad	OL of Sorrows
Heating System	Radiator Heating	In-floor Heating	Radiator Heating
Air Distributor System	Mixed Flow ventilation	Displacement Ventilation	Mixed Flow Ventilation
Air Condition System	No AC	Limited AC	Full AC
Occupant Comfort	Low	Medium- High	Medium- High
Air Quality	Low	High	Medium
Average Space temperature °C	31	26	24
Electricity Consumption kWh/ft²/year	3.55	6.36	9.14

6. The Board's five year Energy Management Plan 2013 – 2018, approved at the May 2014 Corporate Affairs, Strategic Planning and Property Committee, highlights the Board's overall energy costs and recommends measures to help control utility consumption rates, including adoption of minimum set point temperature of 25° C. for schools with full Air Conditioning. As noted in Appendix C, there is a significant utility and operating cost benefit to the DV and radiant in-floor heating, as compared to central plant AC system, with perimeter heating.

7. A central plant system, with large capacity chiller and cooling tower, is a more effective HVAC model for secondary schools for several reasons noted below;
    a. most secondary school students move from room to room through the course of the day, hence providing 100% fresh air within the room, is not as critical as with elementary schools, where students spend the majority of their day in one classroom;
    b. the cost of installing a central plant and a chiller can be absorbed within the larger construction budget provided for secondary schools;
    c. a central plant with chiller is the more effective model to provide air handling, ventilation and cooling rather than the DV system, which relies on smaller cooling units serving a variety of areas;
    d. as DV relies on stratification (cooler, low volume air rises as it becomes heated), the introduction of supplementary cooling will impact the stratification effectiveness of DV;

8. The operational and maintenance costs for the full AC system are greater than for the DV system. Full AC systems need to be verified and serviced prior to start-up in the spring, and in many cases, as elementary schools are

not occupied in the summer – the systems are turned off at the end of school and then may need to be re-started/serviced for return to school in the fall. AC can be provided for specific areas such as the multi-program room, learning commons, admin area and child care spaces through the use of smaller Variable Refrigerant Flow AC system (VRF). These systems require less maintenance and start-up/shut-down activity than the traditional central AC chiller with cooling tower.

9. DV is able to provide *occupied* room temperatures that range between 25° C. to 26° C. on the "Hot" degree days, which as noted previously may only occur a maximum of 20 - 35 days throughout the school year.

B. EVIDENCE/RESEARCH/ANALYSIS

1. As there are a variety of factors that impact the overall capital costs, including size and location of the equipment, corresponding building area, life cycle (anticipated replacement cost), utility costs, and anticipated maintenance and servicing of the systems. The Table below provides a comparison of the capital and operating costs, of the two systems: This information is based on the recent design for The Holy Trinity, which is a Capital Phase 3 project and OLO Sorrows (for utility/maintenance and operating comparison).

	OPTION 1	OPTION 2
Type of Mechanical Systems/Costs based on the Holy Trinity	Displacement Ventilation, with radiant heat flooring in classrooms & resource rooms + three Cooling Centers with AC (Learning Commons, Multi-purpose Room & Admin Area)	Wall-fin Perimeter Heating, with Central Plant for Ventilation and Air Conditioning, with two gas-fired mid-efficiency boilers
Building Area Sq Metres	5,046	4,973
Approx. Cost of Mech System	$1,534,000	$1,652,000
HVAC Cost per Sq Metre	$ 304	$ 332
Approx Cost of Building	$ 10,106,000	$ 10,109,000
Percentage of HVAC Cost to Bldg Costs	15.18%	16.34%
Estimated Service Life/YR	25	15/20
Utility Costs/YR	$57,101	$ 78,641
Greenhouse Gas Emission	40,288 kg Equivalent to GHG produced by 150 cars	78,641 kg Equivalent to GHG produced by 291 Cars

Indoor Air Quality	High	Medium to High for 30° degree days
Noise Level	Low	Medium
Comfort Level	Medium to High	Medium to High

The cost difference between the two systems is primarily in the annual energy consumption and annual operation costs. Over a period of 20 years, the anticipated cost savings between the two systems, based on current utility rates and current usage, (no increase) would result in $430,000 in energy saving for the DV/Radiant In-floor Heating verses traditional

perimeter heat/AC, and would require the life cycle replacement of the air conditioning equipment (roof top Air handling Unit), within that time frame.

2. There is no legislation that requires elementary schools to be air-conditioned. Ventilation requirements are prescribed in the Ontario Building Code, as well as through ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers) which is an organization devoted to the advancement of indoor-environment-control technology in the heating, ventilation, and air conditioning (HVAC) industry. In addition, the City of Toronto requires all new buildings to meet certain energy efficiency targets – including levels for Greenhouse Gas Emissions.

   The Ministry of Education (EDU) has space and cost benchmarks for new elementary school construction – based on $178.52/sq.ft. ($1,921.46 sq. m.). Boards may no longer apply Proceeds of Disposition to cover costs above the benchmark, although the EDU has provided additional Capital Priority funding for unique site costs.

   The EDU has also changed the allocation of Grants for Student Needs (GSN), related to Efficient Use of School Space, and reductions to the Top-up Calculations, which will impact the Board's School Operations funding. While the Ministry has indicated there will up additional funding for Utilities, increases in utility rates are anticipated from Toronto Hydro, which may offset any additional funding received by the Ministry. It is therefore critical the Board plan energy efficient and sustainable buildings as a priority.

3. The Toronto District School Board has also adopted Displacement Ventilation as their standard for their new elementary schools – however, they have maintained perimeter heating rather than install radiant in-floor heating. The TDSB only has two schools currently with DV and they are in the process of studying whether perimeter heat is effective, given that most mechanical engineering studies recommend radiant in-floor heating with DV systems to allow the cooler air to be heated more evenly as it traverses the heated floor and rises up, taking contaminants with it. Perimeter heat is not ideal as the heat source is located in a smaller, more concentrated area at the window wall of the room.

Displacement Ventilation is used in Europe and in the USA. California adopted DV for new schools, in recognition of the energy savings and the benefits of providing 100% fresh air to classrooms.

4. The concept of DV with radiant heat flooring was introduced to the Board in 2010, prior to the launch of the Phase 2 Capital Program. At the time, the Board made changes to the standard for elementary schools to include a fully air conditioned library (now Learning Commons) as well as inclusion of a Multi-Purpose Room (also to be full air conditioned).

   For the Capital Phase 3 projects, information regarding DV and radiant in-floor heating was presented to the school design sub-committee. The building sub-committee, including members of the parent council for both St Simon and The Holy Trinity supported the DV system primarily because of the benefits of having 100% fresh air in classrooms throughout the school year, as well as radiant in-floor heating.

5. Building performance data, including energy consumption is routinely collected for all schools. Information from the recently completed Capital Phase 2 schools, (with the exception of St Andre which was only occupied in February) brought about some modifications to mechanical system design and specifications, as recommended in the 2015 Elementary School Design Standards – namely, radiant in-floor heating is only required in the classrooms, learning commons and multi-program room rather than throughout the building. Corridors, admin areas, washrooms and the gymnasium are to be served from conventional heating radiators. This has reduced the construction cost of new schools, without altering energy consumption.

C. VISION

VISION	PRINCIPLES	GOALS
Stewardship of Resources and improving student/staff learning environments	Design and Building caring environments that meet the needs of students , staff and the community, and are within the Ministry-mandated Capital Priority goals and funding requirements;	Management of the Board's Capital funding, meeting curriculum objectives and program needs through responsive design. Managing Utility and Operating costs ;

D. METRICS AND ACCOUNTABILITY

1. Daily temperature and humidity level data is available for the majority of schools equipped with Building Automation Systems (BAS). This data enables staff to monitor temperature settings and to undertake energy-saving measures such as zone-control, night-cooling and other diagnostics. The Board's 2013 -2018 Energy Management Plan provides annual energy consumption rates for all TCDSB buildings, and targets annual energy cost-saving measures while tracking utility costs.
2. A detailed project budget for each new capital project will be provided to the Board prior to tendering the project. The budget will include the estimated cost for the mechanical system. The EDU cost benchmark governs the cost for all new schools. Detailed cost estimates are required to be submitted to the EDU in order to receive Approval to Proceed.
3. The Board's work notification and work order system from regular maintenance and repairs provides additional data regarding the operating costs associated with mechanical systems.

E. IMPLEMENTATION, STRATEGIC COMMUNICATIONS AND STAKEHOLDER ENGAGEMENT PLAN

1. Provide information regarding the various systems to local school community as part of the Design Development process, including data from Capital Phase 2 Schools and provide school communities with an opportunity to visit recently completed elementary schools. School communities shall be informed of the EDU's cost benchmarks, and the process for whether there are constrains that impact the design, including the mechanical system design, for the project.
2. Provide a copy of the 2015 Elementary School Design Standards on the Board's web site.
3. Provide each school with an annual Energy Report card, detailing the amount of energy consumed (Hydro/Natural Gas and Water) per school and providing information related to energy saving measures that can be undertaken by the school, as well as planned/approved Renewal work that is energy related.

F. STAFF RECOMMENDATION

That the 2015 Elementary School Design Standards as detailed in Appendix A be approved.