# Chilled beam technology overview

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**SUMMARY**

The main focus of the paper will be on active beam technology regarding comfort, flexibility and energy. It will explore the use of beam systems and consider these systems in their ability to control temperature and ventilation.

Different activities and different buildings can be more suitable to particular indoor climate technology. In the case of chilled beams the tighter the building envelop the better the chilled beams can perform. This means that they are not limited to a particular type of outdoor climate, as the central air handling system takes care of the supply air temperature and humidity. Different applications can be considered from offices, to hotels and classrooms. An example will be worked through in a mock up test scenario, concentrating on comfort criteria (draught free, low sound level and good mixing characteristics).

The operation of any building system requires maintenance of the life time of the equipment. As chilled beams have no motors, no filters and no drainage piping for condensation the maintenance requirements are minimal. Consequently the installation maintains its value protecting initial investment costs.

The indoor climate systems using active beams will be compared to other conventional and contemporary solutions on energy efficiency, flexibility, comfort and investment. To conclude the presentation will give a series of 'rules of thumb' to help the successful implementation of beams from a system perspective, from humidity control, active comfort control and optimizing energy savings.

## 1 Systems

Energy comparison

The principle way to in which beam technology can minimise energy use for indoor climates is due to the temperature of the water circuit, 14°C supply and 17°C return are typical figures compared with 6°C supply and 12°C return for fan coils. If fan coils are run at higher temperatures they lose cooling capacity. The system variable values used for the comparison are in figure 1.1. The basis for the reduced energy usage in a beam indoor climate system is the chilled water supply (reference figure 1.3).

Figure 1.3 shows the relative plant energy cost comparison for the 4 standard buildings modelled comparing a VAV EC fan coil, passive and active chilled beams[1].

| Reference | Building 1 | Building 2 | Building 3 | Building 4 |
|---|---|---|---|---|
| Footprint | 35m x 50m | 35m x 50m | 35m x 100m | 35m x 100m |
| Storeys | 4 | 8 | 4 | 8 |
| Approximate Office Space | 7000m² | 14000m² | 14000m² | 28000m² |

| System Variable | VAV Fan Coil | Passive Chilled Beam | Active Chilled Beam |
|---|---|---|---|
| Chilled Water Flow | 6.0 °C | 14.0 °C | 14.0 °C |
| Chilled Water Return | 12.0 °C | 17.0 °C | 17.0°C |
| AHU SFP* | 2.1 W/l/s | 2.1 W/l/s | 2.1 W/l/s |
| AHU Heat Recovery | 75% | 75% | 75% |
| AHU Air Supply Temperature | 14.0 °C | 18.0 °C | 16.0 °C |
| Chiller COP | 4.00 | 4.48 | 4.48 |
| Free Cooling DAC Efficiency | 67% | 67% | 67% |
| Free Cooling SFP | 0.4 W/l/s | 0.4 W/l/s | 0.4 W/l/s |

Figure 1.1[1]

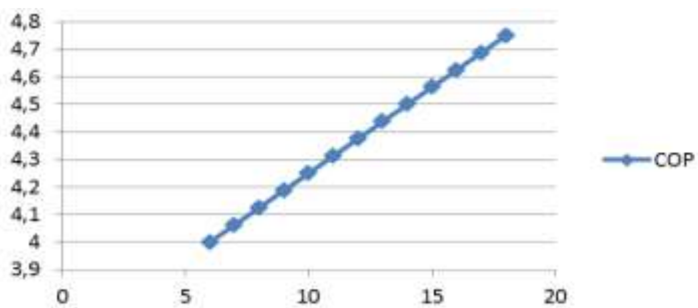


Figure 1.2 Chillers COP v water supply temp (deg C)

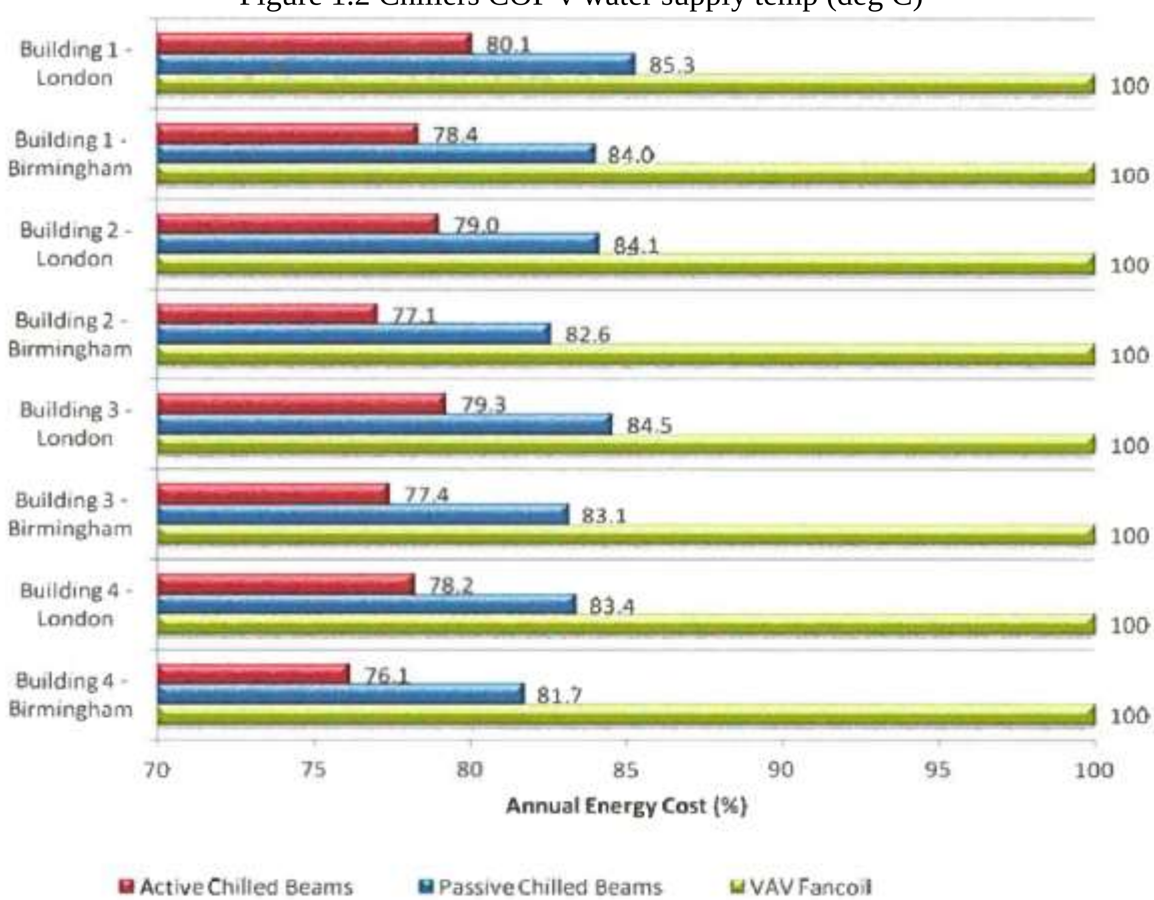


Figure 1.3[1] Annual Plant Energy Cost Comparison

Free cooling.
Due to the relatively high cooling temperatures that beams are designed to operate at free cooling can be employed if the outdoor climate is suitable.

Maintenance.
The cost for maintaining a chilled beam amounts to no more than collecting any dust from the coil, which is recommended annually. Fan coils will require filter changes and motor inspections.

**2 Indoor Climate**

What do you as a designer need to achieve to reach the requested demands of good indoor climate? The room temperature needs to be right, the sound levels needs to be low, there should not be any draught issues and the air quality needs to be good. These demands can all be handled by chilled beams.

Cooling capacity is achieved by induction technology. Since there is no fan in the chilled beam the driving force is created by supply air distributed by an Air Handling Unit (AHU). By building up a static pressure (normally 50-120 Pa) in the plenum of the chilled beam the supply air can be distributed through small nozzles at high velocity (figures 2.1-3). The high velocity air cause the surrounding air (next to the nozzles) to mix with the supply air creating an under pressure above the water coil. The under pressure forces room air through the water coil which then can be cooled or heated depending on the current demand.

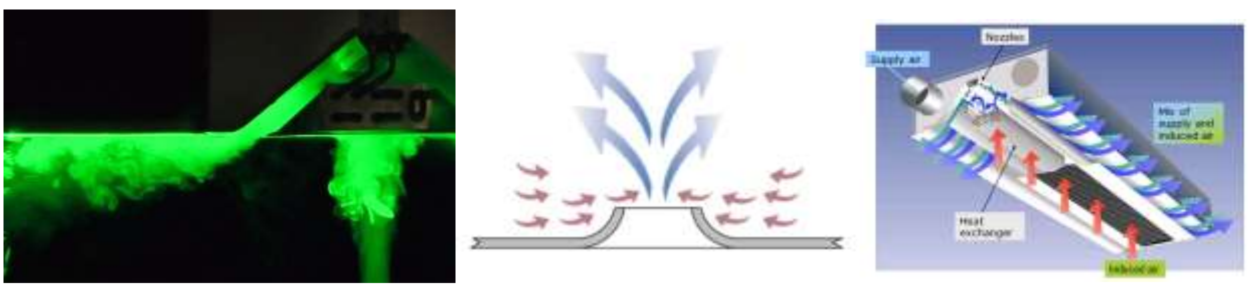

Figure 2.1,2.2 and 2.3. Induction

In commercial buildings, demands for low sound levels are normally quite tough to achieve. The demands vary from country to country but in most cases the sound pressure levels should be less than 30 dB(A). Since there is no internal fan in a chilled beam the sound generation is very low as long as the system is designed, installed and commissioned correctly. Sound generation by chilled beams is normally originated from the supply air inlet and/or by the nozzles.

One of the most important issues for a good indoor climate is to create a draught free environment. To ensure low air velocities in the occupied zone there are a few important things to take into account. First of all the cooling capacity from the chilled beams should be selected to the actual demand. An oversized system can cause temperature swings in the room resulting in unnecessary comfort reduction. Oversized (figure 2.4) systems also have a negative influence on the installation cost in terms of larger AHU, chiller, pipes and ducts than necessary.

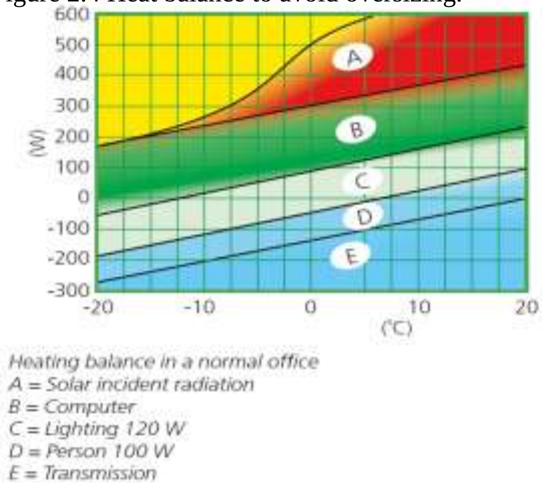

Figure 2.4 Heat balance to avoid oversizing.

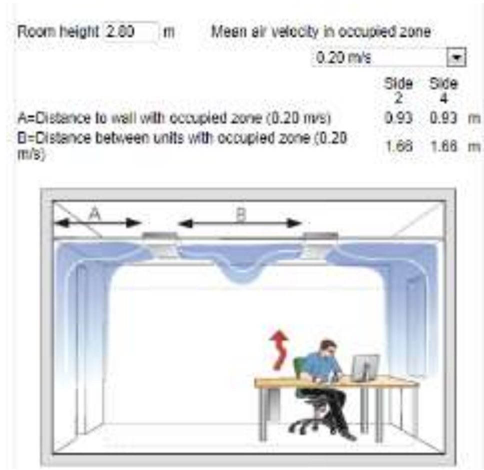

Figure 2.5. Software support for positioning of chilled beams.

Secondly the positioning of chilled beams should be considered to avoid risk of draught. Depending on the nozzle pressure, airflow and capacity chilled beams should have a minimum distance between the units and also to walls and/or other affecting obstacles. Most manufacturers have software available to support guidelines of positioning (figure 2.5).

In general the most effective way to achieve a draught free environment is to use as much of the unoccupied zone as possible to distribute the air into the room (ceiling and wall areas). It is also wise to consider possible future changes in the room layouts at a very early stage. A chilled beam system can be designed as a very static system but also as a very flexible system. Office buildings of today are often built on modular zones, where partition walls can be installed or removed creating open space offices, cell offices and conference rooms. This requires a system that can be adapted to changes in terms of airflow, capacity and air distribution.

A proactive design will ensure a minimum need of redesign such as piping, ducting and controls securing good indoor climate for many years to come. In the proactive design it is also important to secure the distribution of air (AHU size) and water (chiller size).

Good air quality is just as important as correct room temperature, low sound levels and low air velocities to achieve a good indoor climate. In a system with active chilled beams supply air serves two purposes. As mentioned above one purpose is to create induction. The other purpose is naturally to supply fresh air to the room. The total airflow in a chilled beam system must be designed to:

1. Meet requirements stated by rules and regulations concerning air quality.
2. Achieve the required cooling capacity (air + water).
3. Evacuate moisture from infiltration and people.

In a cold/dry climate it is normally enough to supply an airflow that meets the regulations. In a warm/humid climate it is more common that the supply air volume needs to be designed to evacuate moisture. This will then be more than enough air flow to cover rules, regulations and capacity requirements. Since chilled beam systems are designed to “run dry” without any condensation on the coils the dew point of the room air needs to be lower than the supply water temperature. This is one of the most significant differences between the most common fancoil systems/VRV systems and chilled beam systems. Fancoils/VRVs handle both sensible and latent cooling in the room while chilled beams handle the sensible cooling in the room and the latent cooling in the AHU. There are pros and cons for all of the mentioned systems. In general the pros for chilled beams are less need of maintenance and better room comfort. The pros for fancoil/VRV:s are low demands on central humidity control and higher cooling capacity per $m^2$.

## 3 Summary

Summary (design rule of thumbs).

- Avoid oversizing of the system for comfort reasons and economic reasons.
- Proactive design. Think long term, static or flexible, keep options open when positioning and consider local & overall capacity.
- See the total building as a system; a good envelop enables optimal system choice. Low infiltration and good window selection are key.
- Optimise the comfort use unoccupied space to distribute the air and use product features to your advantage.
- Quality installation equals designed functionality. Tight ducting with minimal leakage gives good economy and functionality. Low pressure drops give low sound levels and good economy. Commissioning is simplified.

Figures 2.6 , 2.7 and 2.9 show the typical air velocities, temperature profile and average time of the air in the space using beam technology.

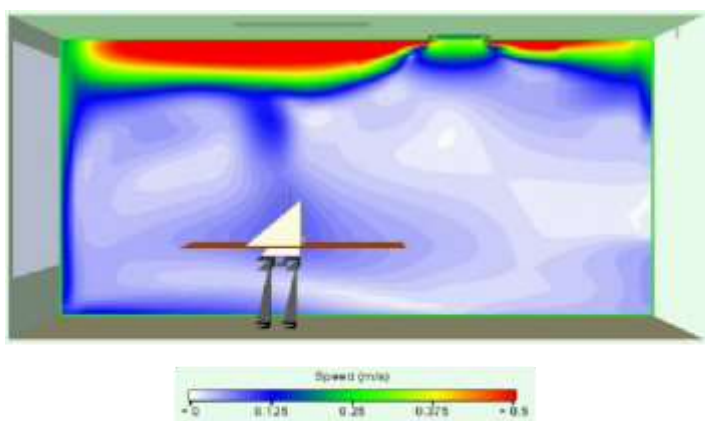


Figure 2.6 Typical air velocities in a cell office.

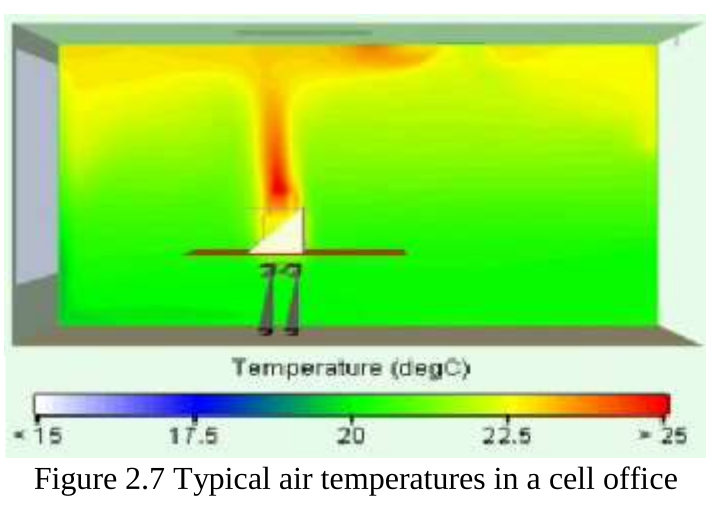


Figure 2.7 Typical air temperatures in a cell office

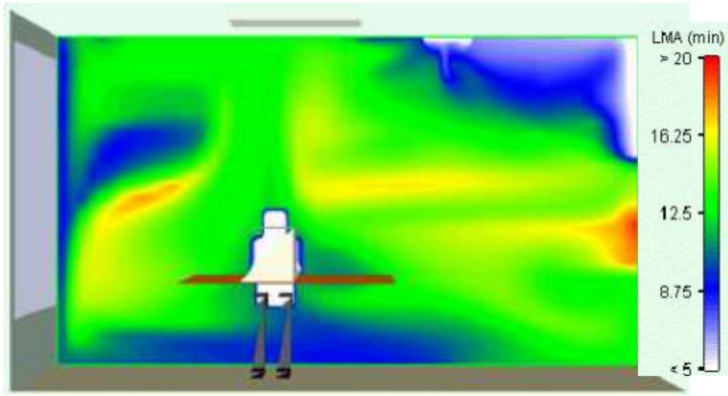

Figure 2.8 Typical age of the air in a cell office (LMA = Local Mean Average in minutes)

Lab mock-up test; Open plan office.


Figure 2.9

Figure 2.9 pictures the mock up room set up, as both an open office area for 4 people and a conference area. Figures 2.10, 2.11 show cross sectional and plan views of the mock up test.
In cooling mode the primary air flow rates for the office areas were 30m$^3$/h per beam (induction module) where low velocities were throughout the room and for the conference room 95m$^3$/h the DR index was higher, but only above 15 in a few insignificant positions. Figure 2.12 shows the results from plane A-A which is over 4 of the desks and clearly shows a comfortable environment for office work.

Figure 2.10 Side and top view plans of mock up test.

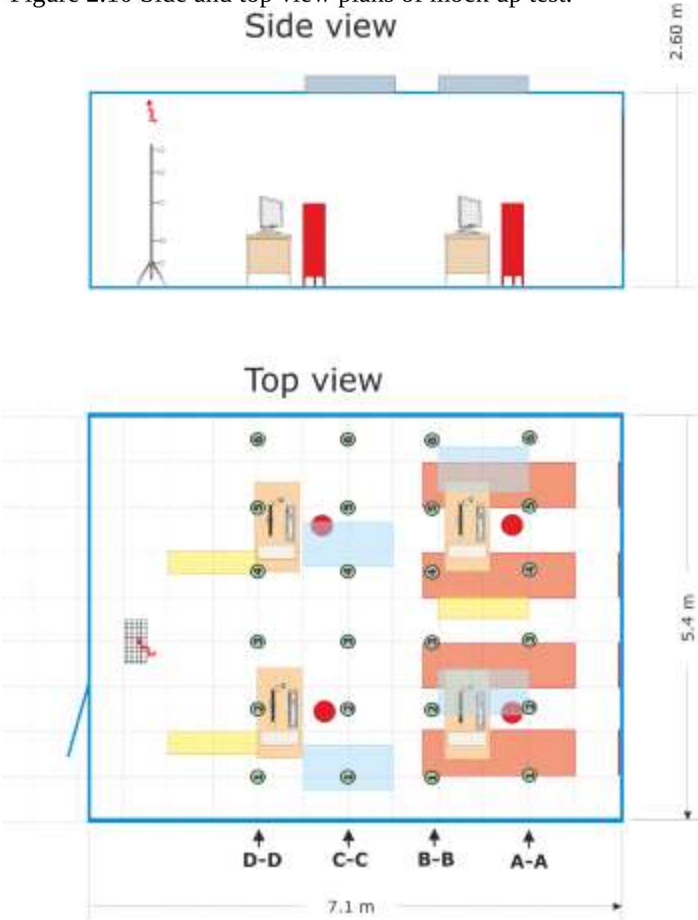


Figure 2.12 Results velocity, turbulence, temperature and draught

**Plane A-A**

**Velocity ( m/s )**

| | Pos 1 | Pos 2 | Pos 3 | Pos 4 | Pos 5 | Pos 6 |
|---|---|---|---|---|---|---|
| 1800 | 0.08 | 0.11 | 0.12 | 0.09 | 0.11 | 0.12 |
| 1500 | 0.08 | 0.14 | 0.12 | 0.08 | 0.12 | 0.12 |
| 1100 | 0.09 | 0.17 | 0.14 | 0.07 | 0.12 | 0.10 |
| 600 | 0.15 | 0.14 | 0.13 | 0.06 | 0.14 | 0.10 |
| 100 | 0.14 | **0.18** | 0.13 | 0.17 | 0.15 | 0.14 |

*min measured value 0.05m/s

**Turbulence intencity ( % )**

| | Pos 1 | Pos 2 | Pos 3 | Pos 4 | Pos 5 | Pos 6 |
|---|---|---|---|---|---|---|
| 1800 | 50 | 51 | 34 | 35 | 33 | 26 |
| 1500 | 60 | 51 | 39 | 39 | 38 | 28 |
| 1100 | **60** | 24 | 39 | 48 | 37 | 37 |
| 600 | 33 | 31 | 48 | 55 | 31 | 43 |
| 100 | 29 | 24 | 30 | 32 | 27 | 33 |

**Temperature ( °C )**

| | Pos 1 | Pos 2 | Pos 3 | Pos 4 | Pos 5 | Pos 6 |
|---|---|---|---|---|---|---|
| 1800 | 24.9 | 25.0 | 25.1 | 25.2 | 25.2 | 25.2 |
| 1500 | 24.7 | 24.9 | 24.9 | 25.0 | 25.0 | 25.0 |
| 1100 | 24.8 | 25.2 | 25.0 | 25.1 | 25.1 | 25.1 |
| 600 | 24.7 | 25.1 | 25.2 | 25.2 | 25.2 | 25.2 |
| 100 | 24.7 | **25.4** | 25.3 | 24.9 | 25.2 | 24.9 |

**Draught rating**

| | Pos 1 | Pos 2 | Pos 3 | Pos 4 | Pos 5 | Pos 6 |
|---|---|---|---|---|---|---|
| 1800 | 5 | 8 | 8 | 5 | 7 | 7 |
| 1500 | 5 | 11 | 9 | 5 | 9 | 7 |
| 1100 | 7 | 11 | 11 | 3 | 8 | 7 |
| 600 | 11 | 9 | 11 | 2 | 10 | 6 |
| 100 | 10 | 12 | 9 | **12** | 9 | 10 |

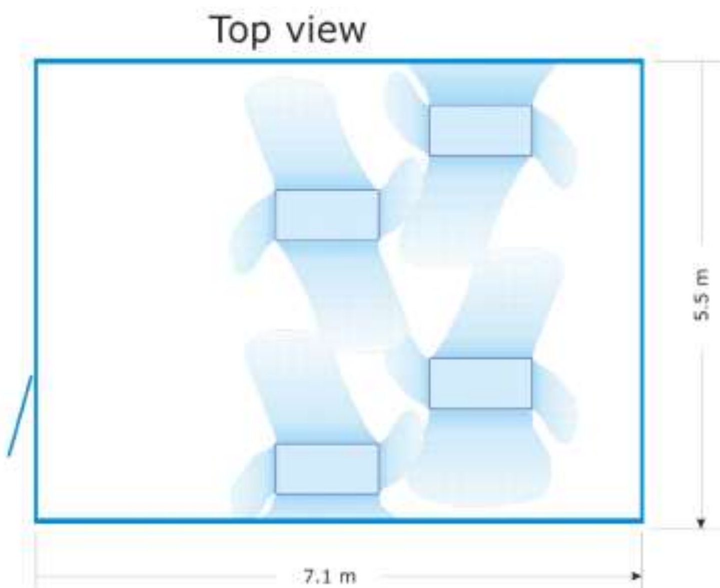


Figure 2.11 Top view air pattern in the test, created by guide fins to avoid draught.

## 4 Discussion

Beam indoor climate technology has the ability to offer a high level of comfort to the users. Mock up tests show that indoor climate parameters are extremely comfortable and can provide the basis of the indoor climate system for many decades with minimal maintenance at the room level. Energy usage of beam system can be significantly lower than other indoor climate systems due to the higher chiller temperatures on a system level or at least reduced cooling loads at lower chilled water temperatures.

## 5 References


1. CBCA Technical fact sheet 2 EDSL Tas energy study. Summary findings. June 2013.
2. CIBSE journal November 2013.