THE UNIVERSITY OF
WAIKATO
Te Whare Wānanga o Waikato

Assessment of the performance of the Showerdome™ device

A technical report prepared for
Showerdome Ltd

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Summary

Showerdome Ltd (Tauranga, New Zealand) manufacture a device (the *Showerdome*™) that traps moisture within a shower cubicle, restricting its release into the bathroom which in turn greatly reduces the amount and likelihood of condensation (and its associated negative effects) outside the shower cubicle. Showerdome Ltd approached the University of Waikato seeking an independent, quantitative assessment of the performance of their device to support their existing appraisals which have mainly been qualitative and anecdotal.

Testing on the effectiveness of the Showerdome™ was carried out in a domestic bathroom in Tauranga, New Zealand during December 2010 and January 2011 (Summer) and also during August and September of 2011 (Winter). The experiments showed that with a Showerdome™ installed the relative humidity within the bathroom was largely unchanged during a 5-15 minute shower. These results have significant implications for a typical household. The amount of moisture that would escape during a 15 minute shower in a cubicle that does not have a device such as the Showerdome™ is of the order of half a standard cup (125 ml). While some of this water might exit the home via ventilation, any which does not escape will either condense on surfaces inside the home or remain in the air (increased humidity). Condensation serves to accelerate the growth of harmful moulds and bacteria, and contributes to structural damage. In addition, the more humid the air is, the more energy is required to heat it. While the Showerdome™ is not a dehumidifier (i.e. it does not remove moisture from the air, so it will not reduce background humidity) it does prevent the shower from increasing the humidity of the air and forming condensation.

Assuming that the Showerdome™ is installed and used correctly, there is the potential for significant energy savings to be made (in the region of hundreds of dollars per year, depending on a number of factors), mainly from reduced usage of electric heaters to dry the bathroom after a shower (or to pre-heat the bathroom if the window has been left open to dry it). The Showerdome™ would render extractor

fans and mirror de-misters largely redundant, which would result in a small energy savings in each case, but would also result in reduced capital costs, since their installation (particularly in the case of the de-mister) would be unnecessary. There would also be energy savings if the occupants of a dwelling stopped using heated towel rails as a result of installing a Showerdome™. Indirect savings related to reduced maintenance and health-care costs may also result from the installation of a Showerdome™.

In drawing these conclusions, it must be stressed that while a properly installed Showerdome™ will definitely prevent moisture from leaving the shower and causing condensation and fogging in the bathroom, it will not necessarily result in energy savings, unless the occupants change their behaviour. If they continue to use heaters, towel rails, extractor fans etc. as they did before the installation of the Showerdome™, then clearly there will be no energy savings.

1 Introduction

Cold damp homes, a particular problem for New Zealand, have a detrimental effect on residents' health due to moulds, mildews, mites and harmful microbes that thrive under such conditions [1,2]. Baths and showers inevitably produce warm moist air, which in a cold, poorly ventilated house is likely to condense on the surfaces of walls, ceilings and household chattels. In addition, excessive amounts of condensation can lead to structural damage as paint peels exposing the wood or wood products that the building is constructed from, which may then either rot or swell and soften.

Showerdome Ltd (Tauranga, New Zealand) manufacture a device (the *Showerdome*™) that traps moisture within a shower cubicle, restricting its release into the bathroom which in turn greatly reduces the amount and likelihood of condensation and its associated negative effects outside the shower cubicle. Showerdome Ltd approached the University of Waikato seeking an independent, quantitative assessment of the performance of their device to support their existing appraisals which have mainly been qualitative and anecdotal.

Since the Showerdome™ is a relatively new device, no standard testing procedures could be found. Instead a series of experiments were performed (as described in Section 4) comparing the moisture loss from a shower with and without the Showerdome™ in order to assess its effectiveness at trapping moisture. Theoretical calculations of energy savings were also performed.

The majority of the work was performed by Mr Luke van Dijk who had recently completed the academic components of his Bachelor of Engineering with Honours Degree at the University of Waikato and was completing the final workplace experience requirement. Luke was supervised by Dr James Carson, a Senior Lecturer within the School of Engineering at the University of Waikato.

2 The Showerdome™

The Showerdome™ works by isolating the warm, moist air within the shower cubicle, since if it does not escape the shower, no condensation will form on surfaces within the bathroom. Also, as the air within the shower is heated, no 'fogging' occurs within the cubicle either.

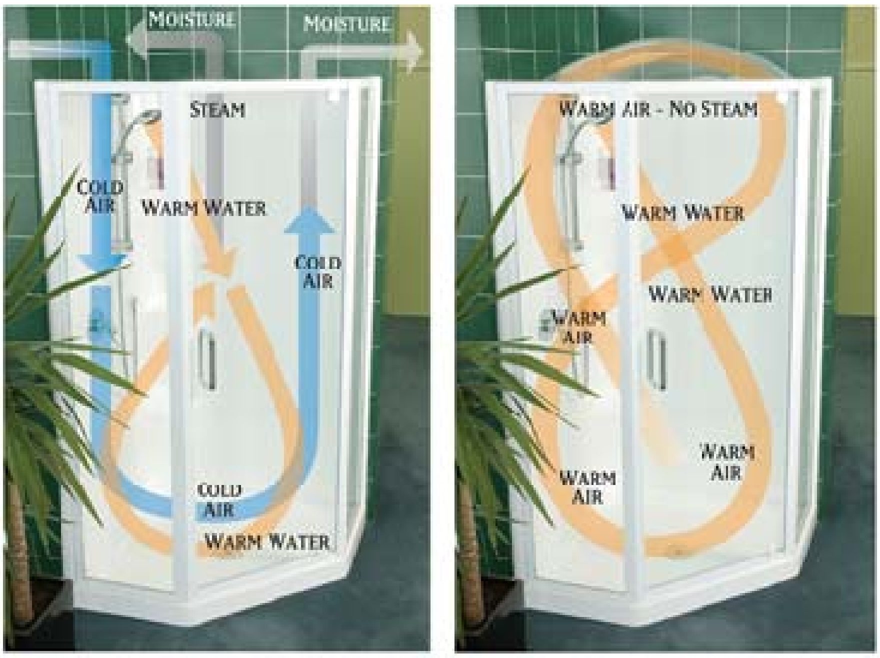

Figure 1 – Showerdome Ltd's marketing graphic showing how the device works

Showerdome Ltd claim many benefits result from the installation and use of the device. These fall into two general categories;

1. Reduced moisture in the bathroom and household
2. Reduced energy use domestically

Within these broad benefits fall many specific claims, which are communicated for marketing purposes;

- Reduced mould and mildew
- Reduced maintenance
- No condensation upon mirrors
- Dryer environment for towels etc
- No need to extractor fans, heated towel rails, or bathroom heat lamps
- Reduced water temperature used at shower head
- No need to keep bathroom window(s) open

Showerdome Ltd bases these claims upon anecdotal evidence from directors, and installers as well as feedback from customers.

3 Theory

3.1 Humidity

At a particular temperature, air can hold a certain amount of water, known as its 'humidity'. There are three commonly used measures of humidity: the absolute humidity is the mass of moisture within the air relative to 1 kg of dry air, the relative humidity, as the name suggests, measures how close to saturation the air is (misting, fogging or condensation occurs once the relative humidity increases past 100%), while the dewpoint is the temperature at which air with a certain absolute humidity will be saturated [3]. These three measurements are related to each other, and are often shown on a psychrometric chart, which may be found in a number of reference books, and on the internet [4].

When a shower sprays hot water through unsaturated air some of the water evaporates and becomes vapour and the air temperature and humidity increase (the relative humidity will typically rise to 100%, i.e. the air will be saturated with water). The warm, water-saturated air rises and, in the absence of a moisture barrier, will escape from the shower cubicle to mix with the surrounding air in the room, thereby increasing the room's humidity. If the dew-point of the air in the room rises above the surface temperature of the walls, ceiling, windows, mirror etc., any air in contact with these surfaces will be cooled below its dew-point temperature with the result that saturated air will release the moisture it cannot hold, which condenses on the surfaces. Therefore, to prevent condensation the dew-point of the air in the bathroom must be maintained below the temperature of the air any surface within the room. This may be achieved either by heating the room or by restricting the amount of moisture being released into it (or a combination of both).

To test the effectiveness of the Showerdome™ as a moisture trap, it is sufficient to compare the relative humidity (or dew-point) of the air in a bathroom during a shower with and without a Showerdome™ installed.

3.2 Energy 'consumption' in a bathroom

Energy usage within bathrooms is highly dependent on both bathroom design and the preferences of the bathroom users, so it is difficult to perform experiments that will produce results from which meaningful, general conclusions may be drawn. It is more practical and potentially more valuable to consider a range of hypothetical usage scenarios and how they would be affected by the installation of a Showerdome™.

4 Experimental method.

Testing on the effectiveness of the Showerdome™ was carried out in a domestic bathroom in Tauranga, New Zealand during December 2010 and January 2011 (Summer Trials), and then August and July 2011 (Winter Trials). A Showerdome™ was professionally installed into a corner shower cubicle (new seals were placed around the doors as part of the installation procedure). The bathroom dimensions were 2.6 m x 1.75 m x 2.35 m, and it had one window and one door. There was no extraction fan, and the bathroom window and door were closed during the trials.

A trial consisted of recording the air temperature and humidity in the bathroom for not less than 3 minutes before the shower was turned on (in order to obtain base-line temperature and humidity readings) followed by running the shower for not less than 5 minutes and not more than 20 minutes at a flow-rate of between 9 and 10.5 L min^{-1} (as per EECA recommendations [5]) with the water temperature ranging between 37 and 40 °C. The air temperature and humidity where measured by a Jaycar Humidity Logger (Jaycar Cat. # QP6013 [6]) and recorded every 2 seconds. The humidity sensor was calibrated during the investigation (Appendix A). Summer Trials were performed 5 times with the Showerdome™ installed and 5 times without it. The Winter trials involved 3 trials with and 3 trials without the Showerdome™.

5. Results

5.1 Summer Trials

Figure 2 shows a plot of the relative humidity in the bathroom with and without a Showerdome™ on a day the 27th of January 2011.

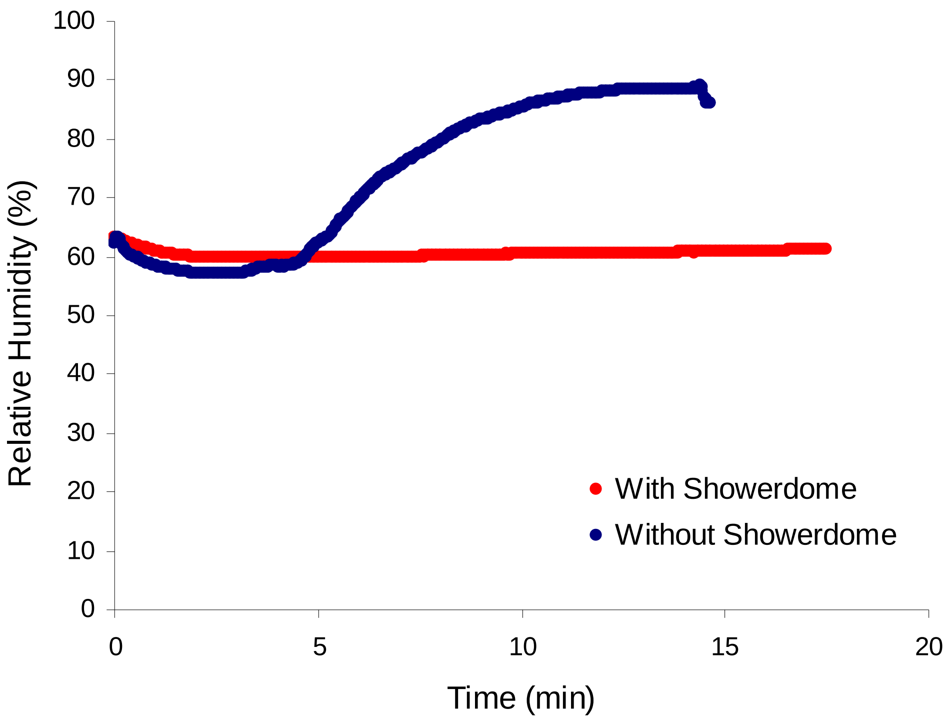

Figure 2: Comparison of relative humidity within a domestic bathroom with and without a Showerdome™ fitted to a shower (27th January 2011)

These results are typical of the Summer Trials performed and show that with the Showerdome™ in place there was no noticeable change in relative humidity. Without the Showerdome™ the relative humidity increased from approximately 60 – 65 % to between 90 and 100%.

Figure 3 shows plots of the air temperature and dew-point in the room corresponding to the relative humidity data shown in Figure 2.

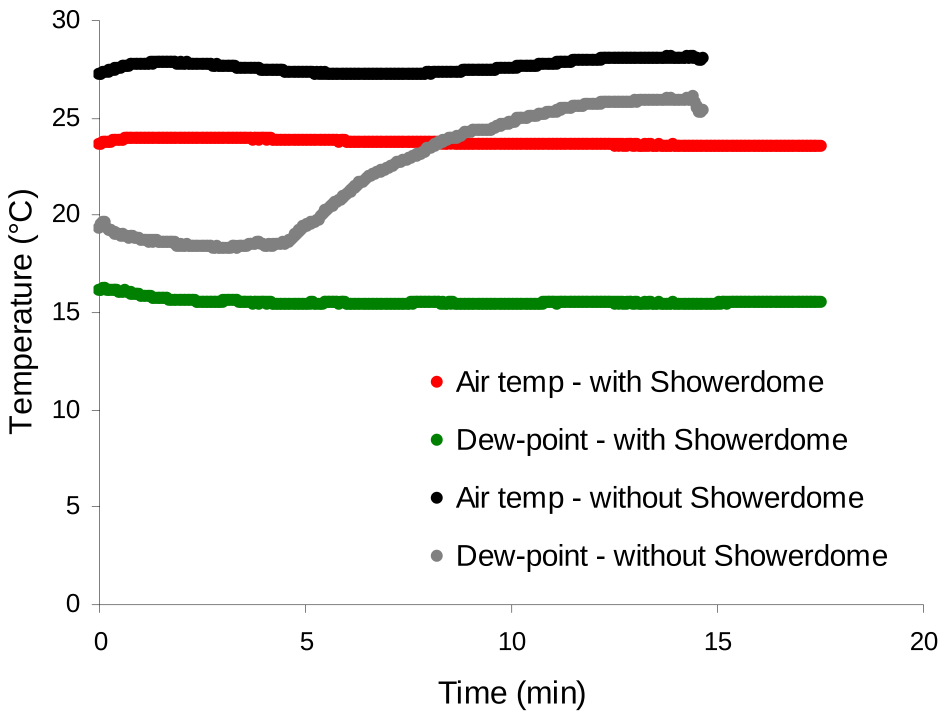

Figure 3: Comparison of air temperatures and dew-points within a domestic bathroom with and without a Showerdome™ fitted to a shower (27th January 2011)

Note that although the air temperature had increased from approximately 24 °C to approximately 27 °C by the time the trial without the Showerdome™ was performed, the results may still be compared, since we are interested with the dew-point temperature relative to the air temperature. As for the relative humidity measurements, there was very little change to the air temperature or dewpoint when the Showerdome™ was in place, whereas without the Showerdome™ the dewpoint rose in the same manner as the relative humidity, and approached the air temperature. Recall (Section 3) that if the dew-point temperature increases above the air temperature a mist will form in the air. Since the temperatures of the surfaces within the bathroom (e.g. walls, ceilings, mirrors etc.) will often be lower than the air temperature condensation may form (as was observed in these experiments) even while the dewpoint is below the air temperature.

5.2 Winter Trials

Since the problem of condensation is more significant during Winter months and the initial trials were performed during Summer, Further trials were performed in August and early September. Figure 4 shows the relative humidity with and without the Showerdome™ for trials performed on August 7th 2011 when the air temperature (dry-bulb) was approximately 11 °C.

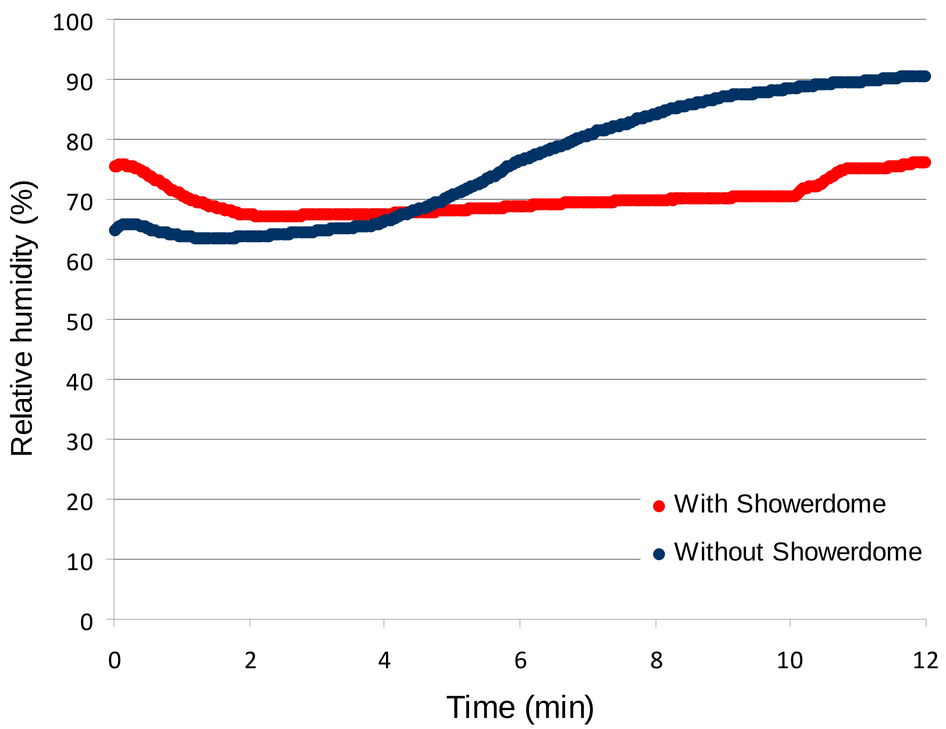

Figure 4: Comparison of relative humidity within a domestic bathroom with and without a Showerdome™ fitted to the shower (7th August 2011)

The relative humidity plots in Figure 4 are similar to those in Figure 2 in that without the Showerdome™ the relative humidity within the bathroom rose from between 60 and 70 % to above 90%, while the relative humidity with the Showerdome™ fitted is lower.

It is worth commenting on the relative humidity data with the Showerdome™ installed (Figure 4), since it is not as flat as the Summer Trial data, and contains to features (‘bumps’ in the curve) that should be explained. The ‘bump’ that occurs at the start of the trial (up to shortly before the 2 minute mark) most likely corresponds to a pulse of warmer air coming in (with its associated moisture) with the opening of the bathroom door as Luke van Dijk entered to start the run. This ‘bump’ in the relative humidity at the start of the run is also seen (to a lesser extent) in the data without the Showerdome™ (Figure 4) and was also observed in other trials, along with corresponding ‘bumps’ in the air temperature data. This initial ‘bump’ was not observed during the Summer Trials most likely because the temperature difference between the bathroom and the rest of the house was not nearly as significant, and hence the opening of the bathroom door would not have resulted in the infiltration of a significant quantity of air at different temperature or relative humidity.

After the 2 minute mark the relative humidity in the bathroom when the Showerdome™ was installed fell to a base-line of approximately 65 % before rising slowly to about 70 % once the shower was turned on at about the 4 minute mark (Figure 4). This gradual rise in relative humidity during the shower was also observed in the other two Winter Trials with the Showerdome™ fitted. Unlike the Summer Trials, where the relative humidity in the bathroom was largely unaffected with the Showerdome™ in place, Figure 4 shows a small rise in relative humidity as the shower progresses; however it was not significant in terms of producing condensation; in fact no condensation was observed during the Winter Trials with the Showerdome™ in place (until the shower door was opened at the end of the run), whereas extensive condensation was observed during the trials that took place without a Showerdome™ installed.

Another ‘bump’ in the relative humidity data with the Showerdome™ installed may be observed at the 10 minute mark (Figure 4). This most likely corresponds to the shower cubicle door being opened so that the shower could be turned off. Some of the saturated air within the cubicle would have escaped and produced the noticeable increase in the relative humidity within the bathroom. The fact that this ‘bump’ was not observed during the Summer trials may be attributed to the fact that air can hold a lot more water at 25 °C (approximately 20 g water per kg of dry air) than it can at 11 °C (approximately 8.5 kg water per kg dry air), as may be observed on a humidity chart [4]. Hence a given mass of water released into the air at 25 °C will not affect the relative humidity nearly as significantly as it will at 11 °C. Overall the data from the Winter Trials were subject to greater measurement uncertainty due to these temperature sensitivities; however, they nevertheless clearly indicate that the Showerdome™ is an effective moisture trap in Winter as well as in Summer.

The results shown in Figures 2 to 4 have significant implications for a typical household. The amount of moisture that would escape during a 15 minute shower in a cubicle that does not have a device such as the Showerdome™ is of the order of half a standard cup (125 ml), dependent on the dimensions of the room, the duration of the shower and the increase in relative humidity. While some of this water might exit the home via ventilation, any which does not escape will either condense on surfaces inside the home or remain in the air (increased humidity). Condensation serves to accelerate the growth of harmful moulds and bacteria, and contributes to structural damage. The more humid the air is, the more energy is required to heat it. While the Showerdome™ is not a dehumidifier (i.e. it does not remove moisture from the air, so it will not reduce background humidity) it does prevent the shower from increasing the humidity of the air and forming condensation.

6. Potential energy and financial savings

As mentioned in Section 3, due to the wide range of possible energy usage scenarios in New Zealand bathrooms, it is more valuable to perform estimates over a range of variables and conditions than to perform a detailed energy balance around an individual bathroom.

6.1 Reduced heater usage

Firstly, consider potential cost savings associated with reduced electric heater usage. During Autumn, Winter and Spring household residents may dry their bathroom, either by leaving a window open or by keeping an electric heater running for a time after the shower has been exited (or both). Consider a dwelling occupied by four adults (e.g. a typical student flat) who each take daily showers. If there is a drying period of 15 minutes after each shower (or in the case where a window has been left open, a 15 minute pre-heat time to warm the air in the bathroom), that amounts to an hour of heating each day during the colder months which, potentially, is unnecessary. With a Showerdome™ installed there would be no need for this drying (or pre-heating) time.

Customer feedback received by Showerdome Ltd. [7] has indicated that some people report that they don't use their heater at all with a Showerdome™ installed, since the warmth of the moisture vapour is retained within the shower cubicle. Taking the student flat example again, if each occupant of the dwelling takes a 15 minute shower, and either a 15 minute drying or bathroom pre-heating time, potentially two hours of heater usage a day could be saved if a Showerdome™ was installed. While not entirely implausible, this example of the student flat risks over-stating the energy savings. Table 1 shows a range of scenarios, where energy savings are related to reduced electric heater usage (for any reason) and the power consumption of the heater (see Appendix B for example calculations).

Reduced annual energy consumption (kWh)					
Reduced heating time	Heater power consumption (kW)				
(h)	0.5	1	1.2	2	2.4
0.25	46	91	110	183	219
0.5	91	183	219	365	438
0.75	137	274	329	548	657
1	183	365	438	731	877
1.25	228	457	548	913	1096
1.5	274	548	657	1096	1315
1.75	320	639	767	1278	1534
2	365	731	877	1461	1753

Table 1: Potential energy savings from reduced electric heater usage due to the installation of a Showerdome™.

A corresponding array of potential dollar savings is shown in Table 2 (where power is priced at $0.237/kWh).

Reduced annual energy cost ($), assuming electricity costs $0.237/kWh					
Reduced heating time	Heater power consumption (kW)				
(h)	0.5	1	1.2	2	2.4
0.25	11	22	26	43	52
0.5	22	43	52	87	104
0.75	32	65	78	130	156
1	43	87	104	173	208
1.25	54	108	130	216	260
1.5	65	130	156	260	312
1.75	76	151	182	303	364
2	87	173	208	346	416

Table 2: Potential dollar savings from reduced electric heater usage due to the installation of a Showerdome™.

It is not uncommon for bathroom heaters to have power consumptions of 2 kW or 2.4kW, and in such cases, Table 2 shows that a reduction of on average half an hour per day can result in savings in the region of $100/year (the student flat scenario considered earlier would be in the region of $400/year). (It is reiterated that these figures are indicative estimates only, and have not actually been measured in any way.)

6.2 Reduced, extractor fan, and mirror de-mister usage

In addition to reduced power consumption from electric heaters, the Showerdome™ has the potential to reduce energy consumption from other sources. For example, extractor fans may not be required, and mirror de-misters would largely be redundant. However, the power consumption of fans (20 – 50 W) is small compared to the power consumption of heaters, and even if the usage of a 50W fans was decreased by 2 hours per day over an entire year, the energy savings would amount to less than $10/year.

Mirror de-misters ($200W/m^2) are probably more common in hotels than in homes, but regardless of where it is used the energy consumption of the de-mister, while greater than that of an extractor fan, will still amount to tens of dollars per year, rather than hundreds of dollars. However, since the Showerdome™ makes the mirror de-mister redundant, the greatest savings (dependent on the price difference between the de-mister and the Showerdome™) might come from the removal of the need to install the de-mister in the first place – perhaps a serious consideration for a hotel.

6.3 Heated Towel Rails

While the necessity of the extractor fan or mirror de-mister is greatly reduced or completely removed by the Showerdome™, heated towel rails would not be affected as definitely. The Showerdome™ will keep the bathroom drier, which in turn will allow towels to dry faster; however, if people appreciate the warmth of a towel as much as they appreciate the fact that it is dry, it seems reasonable to assume they will probably still use one even with the installation of a Showerdome™. But if a dwelling does stop using heated towel rails as a result of installing a Showerdome™, indicative values of the savings can be seen from Table 3, depending on the power consumption and time of usage.

Reduced annual energy consumption (kWh)			
Reduced Towel	Towel Rail Power Condumption (kW)		
Rail Usage (h/day)	0.08	0.15	0.2
1	29	55	73
2	58	110	146
6	175	329	438
12	351	657	877
24	701	1315	1753
Reduced annual energy cost ($), assuming electricity costs $0.237/kWh			
1	7	13	17
2	14	26	35
6	42	78	104
12	83	156	208
24	166	312	416

Table 3: Potential energy and dollar savings if heated towel rails are no longer used as a result of the installation of a Showerdome™.

It is clear from Table 3 that if a dwelling stops using a heated tower real as the result of installing a Showerdome™ to the savings will be comparable to those from reduced heater usage, particularly if the towel rail is left on 24 hours/day throughout the year.

6.4 Indirect savings

The estimated savings from reduced usage of electrical appliances is relatively straightforward to calculate; however, the indirect savings associated with drier bathrooms may potentially be greater. The two main areas are: firstly reduced maintenance costs such as painting and cleaning, or even replacement of timber framing or other components, and secondly reduced medical expenses from treating health problems caused by damp homes [1]. Without performing a survey of homes with and without Showerdome™ devices installed, it is difficult to put any numerical values on the potential savings, but householders who have lived in their home for more than a year will probably be able to gauge the significance of the problem of dampness, and hence the value to be gained from the Showerdome™.

7 Conclusion

The experiments showed that with a Showerdome™ installed the relative humidity within the bathroom was largely unchanged during a 10 minute shower (with the exception of the shower door being opened during Winter), meaning that the device was effective at preventing warm moist air escaping from a shower cubicle, which in turn meant that no condensation or fog formed in Summer, and minimal 'fogging' occured in Winter. Since condensation serves to accelerate the growth of harmful moulds and bacteria, and contributes to structural damage, and since energy costs increase with increased air humidity, the Showerdome™ would be a worthwhile investment because it prevents these things from happening as the result of using the shower.

Assuming that the Showerdome™ is installed and used correctly, there is also the potential for significant energy savings to be made (in the region of hundreds of dollars per year, depending on a number of factors), mainly from reduced usage of electric heaters to dry the bathroom after a shower (or to pre-heat the bathroom if the window has been left open to dry it). The Showerdome™ would render extractor fans and mirror de-misters largely redundant, which would result in a small energy savings in each case, but would also result in capital cost savings, since their installation (particularly in the case of the de-mister) would be unnecessary. There would also be energy savings if the occupants of a dwelling stopped using heated towel rails as a result of installing a Showerdome™.

In drawing these conclusions, it must be stressed that while a properly installed Showerdome™ will definitely prevent moisture from leaving the shower and causing condensation and fogging in the bathroom, it will not necessarily result in energy savings, unless the occupants change their behaviour. If they continue to use heaters, towel rails, extractor fans etc. as they did before the installation of the Showerdome™, then clearly there will be no energy savings.

References

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[4]http://en.wikipedia.org/w/index.php?title=File:PsychrometricChart-I.PDF&page=1

[5] http://www.energywise.govt.nz/node/9354

[6] http://jaycar.co.nz/productView.asp?ID=QP6013&keywords=humidity&form=KEYWORD

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Appendix A: Humidity Data-logger Specifications and Calibration

The specifications of the Jaycar humidity sensor/logger are listed below:

- Range: -40-70°C (-40-158°F), 0-100% relative humidity,
- Accuracy: ±1°C (1.8°F), ±3% relative humidity
- Resolution: 0.1°, 0.1% RH
- Memory: 3200 samples
- Battery life: 5 sec rate: 12 months, 10 sec rate: 2.5 years
- Software compatible with Windows 2000, XP & Vista
- Dimensions: 100(L) x 22(W) x 20(H)mm

The calibrated by placing it an sealed container which was partially filled with a saturated salt solution within a temperature controlled environment. At equilibrium the 'activity' of the water in the saturated salt solution (which may be determined by a variety of methods and is widely available in the literature) is equal to the relative humidity of the air in the space above it. For saturated lithium chloride at 20 °C the activity (and hence relative humidity) is 11.8 % [9], while for sodium chloride at 20 °C the activity is 77 % [9]. Figures A1 and A2 show that the humidity sensor agreed with the literatures values within its specified accuracy of ±3% relative humidity.

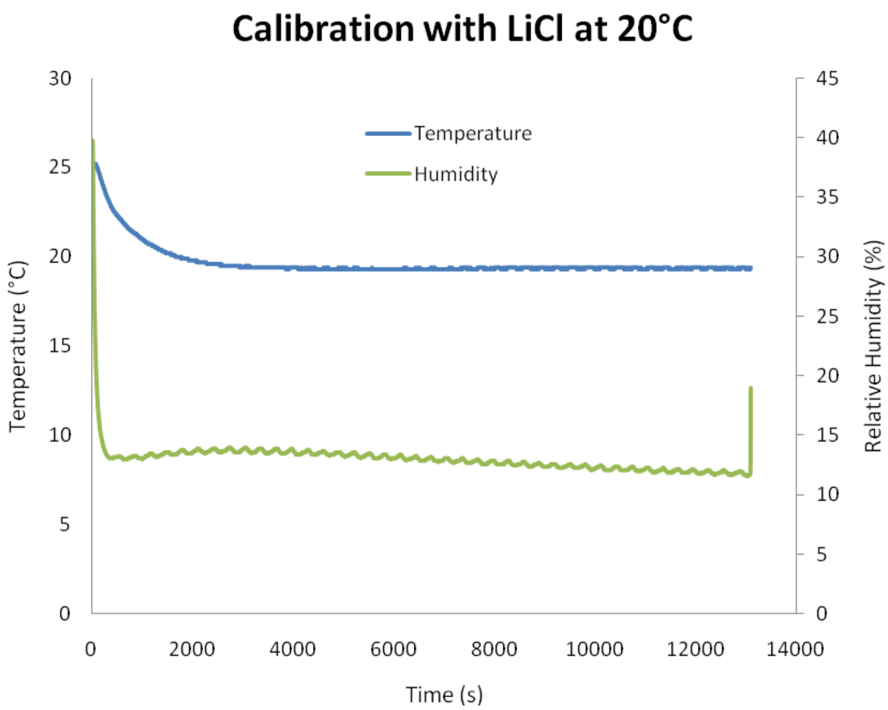

Figure A1: Calibration of humidity sensor with saturated lithium chloride (LiCl) at 20 °C

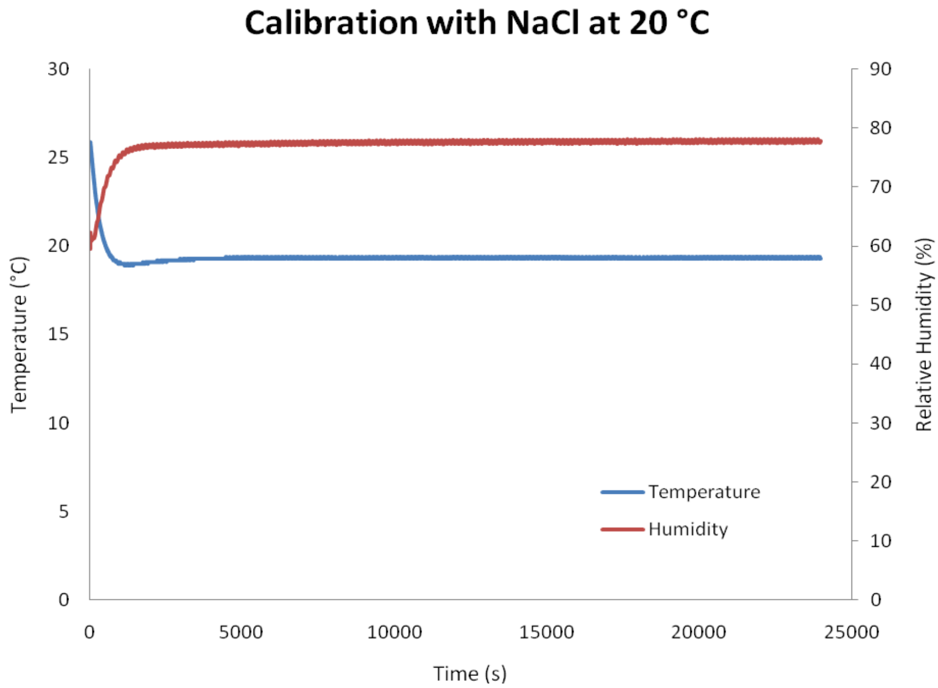

Figure A2: Calibration of humidity sensor with saturated sodium chloride (NaCl) at 20 °C

Appendix B: Example calculations

The energy savings in Table 1 and the top half of Table 3 were calculated from the following formula:

Annual energy saving = power rating x average hours of use per day x days per year

For example, the entry in the top right hand corner of Table 1:

219 kWh/year = 2.4 kW x 0.25 h/day x 365.25 day/year

(Note that figures have been rounded and that the number of days per year is 365.25 rather than 365 to account for leap years).

The savings in Table 2 and the bottom half of Table 3 were calculated from:

Annual dollar savings = Annual energy saving x cost of electricity unit

For example, the entry in the top right hand corner of Table 2:

$52/year = 219 kWh/year x 0.237 $/kWh