University of South Australia

Desktop Study of the Potential of the Plasma Shield System in Reducing Energy and in Contributing Towards Green Buildings

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Executive Summary

A desktop analysis on the potential of Plasma Shield's air purification system (PSS) to allow for a reduction in outside ("fresh") air requirements based on Australian Standards 1668.2 – 2012, and the resultant energy savings that could potentially be realised, has been conducted under simplified conditions relevant to commercial office buildings. This analysis also includes a discussion on the amount of points that could potentially be awarded through the use of the PSS under different rating schemes, namely Green Building Council of Australia's Green Star scheme and the international WELL Building Standard.

The energy analysis was conducted using a simplified model of a commercial office space comprising of a single 100 m^2 enclosure, serviced by a constant volume air handling unit. This estimation was conducted for five major cities in Australia, namely: Adelaide, Brisbane, Melbourne, Perth and Sydney. The results of this analysis (for Adelaide) are summarised in Table 1 below.

Table 1: Summary of results of the simplified model of a commercial office space for Adelaide. Note that here the units W_e and W_t refer to Watt (electric) and Watt (thermal) respectively, while kWh_e refers to kilowatt-hour (electric).

	PSS as particulate filter only	**PSS as particulate filter and odour eliminator**
Reduction in minimum introduced outside air (compared to the case without air cleaning)	25%	65%
PSS filter efficiency required, assuming all return air is serviced by the PSS (%)	3.0%	7.4%
Amount of return air that is required to be serviced by the PSS, assuming a PSS efficiency of 80%	0.3125 L/s per m^2 (or 3.7% of return air flow rate)	0.8125 L/s per m^2 (or 9.2% of return air flow rate)
Reduction in electrical energy per annum	1.22 kWh_e per m^2	3.17 kWh_e per m^2
Reduction in peak plant thermal load	6.1 W_t/m^2	15.8 W_t/m^2
Reduction in peak electrical demand	1.7 W_e/m^2	4.5 W_e/m^2

The assessment of the rating schemes showed that the utilisation of the PSS in building projects may potentially result in:

1) For Green Star Design & As Built v2 (up to 6 points)
    a. Up to 2 points for "Provision of Outside Air", where the use of the PSS facilitates the increase in outside air flow rates relative to minimum requirements by reducing the minimum outside air flow rates required;
    b. Up to 1 point for "Greenhouse Gas Emissions", where the PSS can partially contribute to the overall energy consumption of the building, noting that the employment of the PSS alone is not sufficient in obtaining points in this category;
    c. Up to 2 points for "Peak Electricity Demand Reduction", where the use of the PSS can contribute by reducing the peak electricity demand of the HVAC system, as outlined above. Here it should also be noted that while the employment of the PSS alone is also

not sufficient to obtain points in this category, it does however provide a significant reduction in peak demand;

   d. Up to 1 point for “Innovation”, where it may be argued that the utilisation of the novel PSS comprises an innovative technology.

2) For WELL v2 (up to 10 points)
   a. Satisfying the pre-condition for “Air Quality” required for the different accreditation levels (e.g. Platinum), where the PSS can contribute by reducing the indoor PM2.5 levels;
   b. Satisfying the pre-condition for “Construction Pollution Management”, whereby the PSS can potentially be used as a filter to remove particles in the supply air system, noting that a request for an “alternative” interpretation may be required to allow PSS be classed as a “media filter”;
   c. Up to 2 points for “Enhanced Air Quality”, whereby the PSS may contribute by reducing indoor PM2.5 levels below that required to satisfy the minimum pre-condition requirements;
   d. Up to 2 points for “Enhanced Ventilation Design”, where the use of the PSS facilitates the increase in outside air flow rates relative to minimum requirements by reducing the minimum outside air flow rates required;
   e. Up to 1 point for “Air Filtration”, where the PSS can contribute to achieving 1 point by reducing the PM2.5 levels in the building if the WELL reviewers can be convinced that the PSS be categorised as a “media filter”;
   f. Up to 5 points for “Green Building Rating System”, where the PSS may indirectly contribute to achieving these points by facilitating building projects achieve a green rating (e.g. a Green Star rating, as stated above).
3) For NABERS Indoor Environment Quality (up to 12% of Base Building Rating)
   a. A contribution of the overall star rating through the Indoor Air Quality – Particulate Matter (PM_{10}) category, with the utilisation of the PSS potentially resulting in lower concentrations of PM_{10} particles compared to the reference building. While the NABERS system does not employ a “points” based system, it should be noted that for the “Base Building” category, PM_{10} concentrations are weighted at 12% of the overall rating.

It should also be clearly noted that the employment of the PSS does not guarantee the award of the above points, but rather the above should be used as a guide to determine which categories the PSS could potentially contribute towards.

1 Introduction

Plasma Shield Ltd has developed a novel plasma-based air filtration system that is capable of removing fine particulate matter (PM) from air streams to HEPA-like (or better) levels. The Plasma Shield filtrating system (PSS) has already undergone a series of tests under different conditions and scenarios to show that it is capable of removing PM at efficiencies greater than commonly used porous media filters. The PSS can be mounted within and in-line with standard air-conditioning ducts, allowing to be used generally within the heating, ventilation and air-conditioning (HVAC) sectors.

One of the potential benefits of using the PSS in mechanically ventilated buildings is that the relevant Australian Standards governing the design of ventilation systems, AS 1668.2 – 2012, allows for provisions to reduce the requirements to bring in outside ("fresh") air into the building if sufficient air filtration is provided. This reduction in outside air requirements reduces the energy consumption of the HVAC system by potentially reducing the air flow rates and the need for conditioning the outside air.

Another advantage of the PSS system is that it potentially increases indoor environment quality by removing hazardous PM that may be introduced into the building through the outside air, or that is generated internally within the building itself. This improvement in indoor environment quality is increasingly seen as an important consideration for the design of HVAC systems and buildings in general, with many building rating schemes, such as the Green Building Council of Australia's Green Star rating tool, awarding points for an increased indoor air quality.

UniSA has been engaged by Plasma Shield to conduct a desktop analysis on the potential of their PSS to allow for a reduction in outside ("fresh") air requirements under simplified conditions relevant to commercial office buildings, and to provide an analysis of the amount of points that could potentially be awarded through the use of the PSS under three different rating schemes, namely Green Building Council of Australia's Green Star scheme, National Australian Built Environment Rating System (NABERS) and the WELL Building Standard.

1.1 Aims

More specifically, the aims of the desktop analysis are as follows:

1) Estimate annual energy savings and improvement in NABERS office base building energy rating due to reduction in outside air flow rates, using the rationale under clause 2.8 and Appendix D of AS1668.2-2012, namely "using air cleaning devices to provide an equivalent outdoor air effect", based on the use of a PSS system as the air cleaning device. This will be done under the following assumptions:
    a. The ventilation system is a single-zone (i.e. single enclosure), constant-volume, constant supply air temperature, air-conditioning system treating a typical commercial office space;
    b. Loads and "base case" outside air requirements guided by AS 1668.2 – 2012, AIRAH technical handbook, and other relevant documents;
    c. Outside air conditions follow typical meteorological year data, with the analysis for 5 major cities across Australia (Adelaide, Perth, Melbourne, Brisbane, Sydney);
    d. Under assumed occupancy profiles, e.g. NABERS office base building energy prediction occupancy profiles;
    e. The internal heat loads are constant.

2) Identify points/categories in Green Star, NABERS (Indoor Environment) and WELL rating schemes where the PSS may directly contribute:
    a. Provide a discussion on how the PSS may contribute to achieving these rating schemes.

2 Reduction in Outside Air Requirements

2.1 What the standard says

Australian Standards AS 1668.2-2012 (henceforth called the "Standard") specifies a minimum effective outside air flow rating for each enclosure depending on the usage of each enclosure (Clause 2.8.1). This minimum effective outside air flow rate can be achieved through a combination of methods, including by

- directly bringing air from the outside into the enclosure via the mechanical ventilation system (introduced outside air)
- using "air-cleaning" devices to provide an equivalent outside air flow rate
- using residual outside air that is recycled or transferred from other zones/enclosures

That is, the standard specifies a minimum amount of outside air flow requirement into the conditioned space, with this amount potentially reduced if air cleaning devices (e.g. appropriately rated air filters) are used or where "excess" uncontaminated outside air are transferred across enclosures.

More specifically, the standard provides two (among other) requirements that is relevant to the present discussion on delivering outside air into the conditioned space, namely requirements for

1) A minimum amount of **introduced outside air**
    a. For cases where particulate filtration of the supply air is provided, this value is 7.5 L/s per person
    b. For cases where particulate filtration and odour treatment of the supply air is provided, this value is 2.5 L/s per person
    c. For cases where no air cleaning devices are used, this typically equals to the minimum effective outside air flow rate (see below)

2) A minimum **effective outside air** flow rate
    a. Specified in Table A1 of the Standard, with different values provided for different types of ventilated spaces. For an office area, this value is q_{min} = 10 L/s per person

The actual effective outside air flow rate of the system depends on a range of factors, but comprises of effective outdoor airflow from:

1) Recycled air
2) Transfer air (from another enclosure)
3) Local air cleaning
4) Supply air cleaning
5) Central air cleaning

The methods used to calculate the effective outdoor airflow contribution from each of these is outlined in Appendix D of the standard. The full calculations highly depend on the design of the HVAC system and the air cleaning system employed, however for the purposed of the current study, a simplified single zone office is used as an example in the following section.

2.2 Case Study – Simple Single Zone Office

To illustrate the calculations required to obtain the effective outside air flow rate, and to estimate the energy savings due to the change in the minimum introduced outside air flow rates, we utilise a simple case study comprising of a single zone office serviced by a single, constant volume, air handling unit. We also consider the case where the PSS is used to clean the return air stream only (as shown in Figure 1), and compare this to the case where no air filtration is provided. It is noted that the PSS could potentially be configured as a local air cleaning device (which would also contribute to the effective outdoor air flow rate), however this has not been considered in the present analysis. As such, the only contribution to the effective outdoor air flow is from return air cleaning.

For the purposes of this case study, we also specify the following conditions:

- Floor area, $A = 100\ m^2$ (note that this is arbitrary, with many of the corresponding values below actually scaling linearly with floor area. For example, the calculated energy consumption can be divided by this area to obtain a kWh/m^2 value)
- Occupancy density = $10\ m^2$/person (Table A1 of AS1668) for office areas. The resultant number of people in the space is $n = 100\ m^2 / 10\ m^2$ per person = 10 people
- Cooling load, $L = 100\ W/m^2$ (from AIRAH Technical Handbook)
    - This load is assumed to be constant when the building is occupied, and we assume a 12 hour occupancy period between 7 am to 7 pm (5 days per week)
    - In real applications, the load changes across time and across seasons. However, in the current simplified analysis it is not possible to obtain dynamic loads. Nevertheless, this assumption is reasonable for internal offices that are well insulated with significant equipment (e.g. computers)
- Room design temperature, $T_{room} = 22 \pm 2$ °C
- Off-coil air temperature $T_{off} = 15$ °C (from AIRAH Technical Handbook). This temperature can be varied depending on the design of the HVAC system, however the chosen value here is representative of typical values used by HVAC system designers
- Air conditioning plant coefficient of performance (COP) = 3.5

It is also assumed that the HVAC system allows for economy cycle (i.e. introducing excess outside air when the outside air temperature is lower than the room design temperature for times where cooling is required).

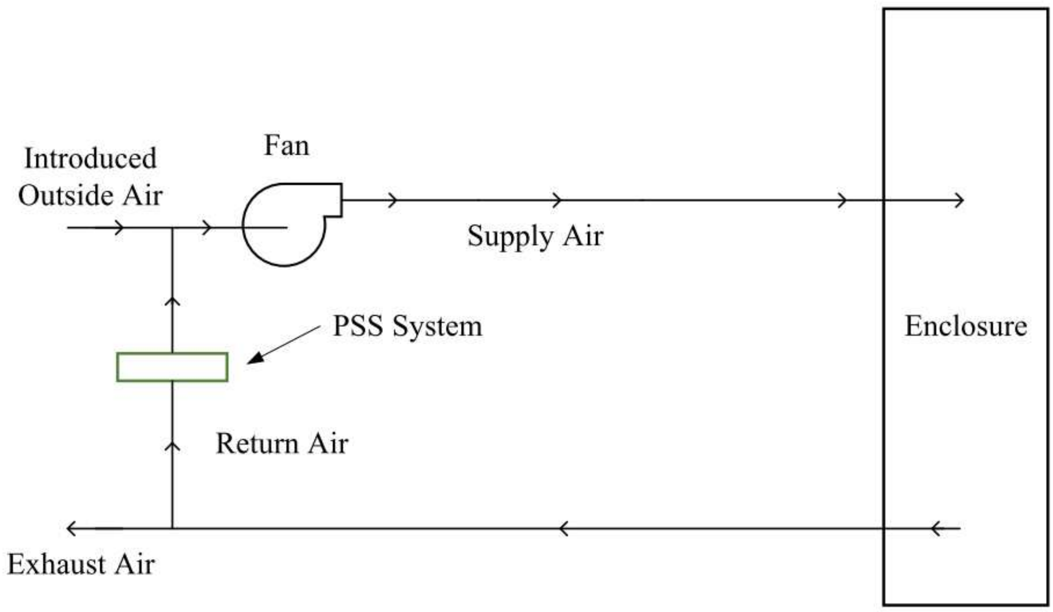

Figure 1: Schematic of single-zone mechanical ventilation system serviced by a PSS system.

2.2.1 Minimum introduced outside air

The minimum introduced outside air flow rate, Q_f, is the higher of two values, namely, the area-based minimum and the occupancy based minimum.

The area-based minimum is the same regardless of whether air filtration is used, and is computed as follows,

$$Q_f = A \times 0.35\,\mathrm{L/s \cdot m^2} = (100\,\mathrm{m^2})(0.35\,\mathrm{L/s \cdot m^2}) = 35\,\mathrm{L/s}.$$

The occupancy-based minimum introduced outside air flow rate depends on the level of air filtration required:

a) For cases where no filtration is required, $Q_f = n \times q_f = 10 \times 10\,\mathrm{L/s \cdot person} = 100\,\mathrm{L/s}$.

b) For cases where particulate filtration is required, $Q_f = n \times 7.5\,\mathrm{L/s \cdot person} = 75\,\mathrm{L/s}$.

c) For cases where particulate filtration and odour treatment is provided, then $Q_f = n \times 2.5\,\mathrm{L/s \cdot person} = 25\,\mathrm{L/s}$.

For a) and b) above, the occupancy-based minimum is greater than the area-based minimum, hence the occupancy-based minimum values are chosen. For the case where particulate filtration and odour treatment is provided, the converse is true. Note that the value of q_f above is the minimum effective outside air flow rates as specified in Table A1 of the Australian Standards, i.e., for office areas this is q_f = 10 L/s per person. The results are summarised in Table 2.

Table 2: Summary of minimum introduced outside air for the present case study

Scenario	Area-based minimum introduced outside air flow rate	Occupancy-based minimum introduced outside air flow rate	Minimum introduced outside air flow rate, Q_f
No air cleaning device utilised	35 L/s	100 L/s	100 L/s
Particulate filtration employed	35 L/s	75 L/s	75 L/s
Particulate filtration and odour treatment employed	35 L/s	25 L/s	35 L/s

The amount of outside air introduced into the enclosure cannot be further reduced below the minimum specified in Table 2 above.

2.2.2 Minimum effective outdoor air

The minimum effective outdoor air flow rate is given by

$$q_{min} = q_f \times n = 10\,\mathrm{L/s\,per\,person} \times 10\,\mathrm{people} = 100\,\mathrm{L/s}.$$

For the present case study where the PSS is employed to filter the return air, with no effective outdoor air being transferred from other zones, the effective outdoor air flow rate is

$$q_{eff} = (Q_s - Q_f)\eta + Q_f$$

where η is the efficiency of the air cleaning device and Q_s is the supply air flow rate.

The required supply air flow rate is dictated by the cooling load, the design room temperature and the off-coil temperature, that is,

$$Q_s = \frac{L \times A}{\rho C_p (T_{room} - T_{off})} = 916\,\mathrm{L/s}.$$

The amount of return air is therefore,

$$Q_r = Q_s - Q_f = 841\,\text{L/s}$$

for the case where the PSS is used as a particulate filter or

$$Q_r = Q_s - Q_f = 881\,\text{L/s}$$

For the case where the PSS is used as an odour eliminator.

If the PSS is used to clean the entire return air, then the minimum required efficiency of the PSS to meet the minimum effective outdoor air flow rate is:

$$\eta_{min} = \frac{q_{\min} - Q_f}{Q_s - Q_f} = \frac{100\,\text{L/s} - 75\,\text{L/s}}{916\,\text{L/s} - 75\,\text{L/s}} = 3.0\%$$

for the case where the PSS is employed as a particulate filter only, and

$$\eta_{min} = \frac{q_{min} - Q_f}{Q_s - Q_f} = \frac{100\,\text{L/s} - 25\,\text{L/s}}{916\,\text{L/s} - 25\,\text{L/s}} = 7.4\%$$

for the case where the PSS is employed as a particulate filter and odour eliminator.

These efficiencies are much lower than the typical efficiency of the PSS, which may exceed 95%. The use of systems with greater efficiencies does not further reduce the energy consumption or the outside air load, because the values of η_{min} above are the values required to meet the absolute minimum introduced outdoor air flow rates; any increase in efficiency cannot reduce the introduced outdoor air flow rates further.

2.2.3 Minimum fraction of return air to be cleaned

As stated above, the use of very high efficiency filters will not necessarily result in a reduction in the required introduced outdoor air flow rates. However, the above scenario is for the case where the entire return air is cleaned by the PSS. An alternative design would be to have only a portion of the return air cleaned, as shown in Figure 2.

In this case, assuming a PSS efficiency of η = 80%, the amount of return air that needs to be serviced by the PSS to achieve the required effective outdoor air flow rates is

$$Q_{s,PSS} = \frac{q_{min} - Q_f}{\eta} = 31.25\,\text{L/s (or 3.7\% of the total return air)}$$

for the case where the PSS is employed as a particulate filter only, and

$$Q_{s,PSS} = \frac{q_{min} - Q_f}{\eta} = 81.25\,\text{L/s (or 9.2\% of the total return air)}$$

for the case where the PSS is employed as a particulate filter and odour eliminator.

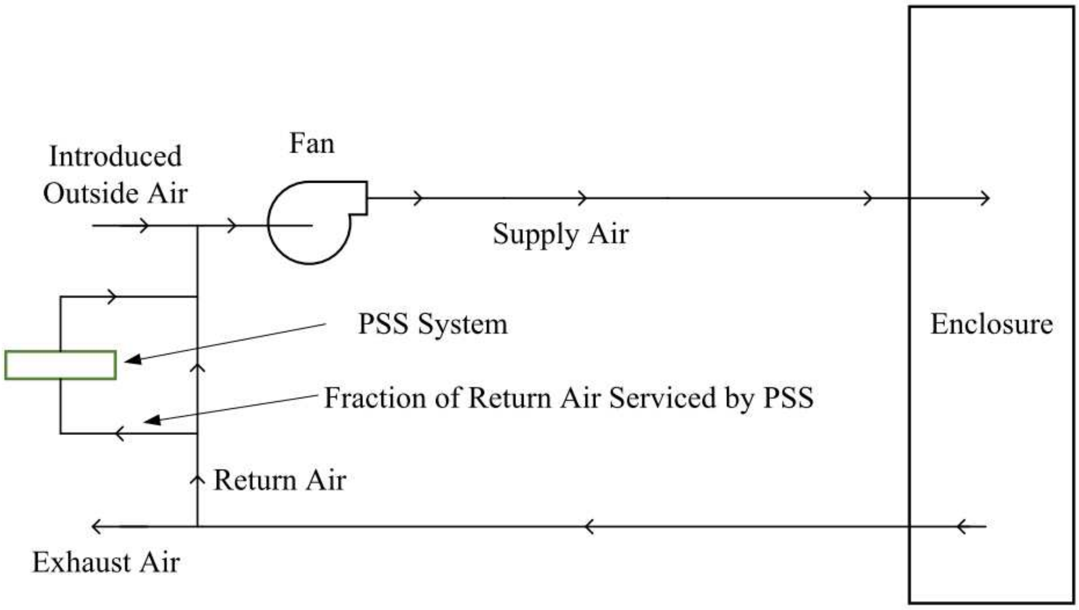

Figure 2: Schematic of single-zone mechanical ventilation system where only a fraction of the return air is serviced by the PSS. Note that the dampers to balance the amount of air bypassing the PSS system is not shown for clarity.

2.2.4 Estimated energy savings

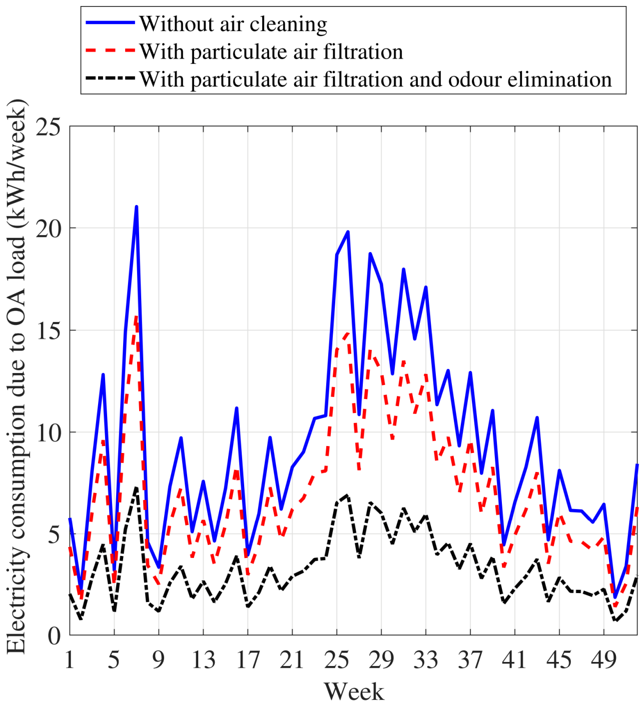

Figure 3: The weekly electrical energy consumed by the HVAC system due to conditioning of the outside air for Adelaide across the whole year, with three different scenarios of air cleaning. The conditioned zone is a simple office occupancy with an area of 100 m^2. Note that week 1 starts on the 1st of January.

Figure 3 presents the results for the weekly electrical energy consumed due to conditioning of the outside air (only) in the case study zone (100 m^2) across the whole year for Adelaide for three different scenarios of air cleaning. The results here show that the HVAC energy consumed to condition the outside air is significant both in the peak summer and winter periods, which is expected. The results also show that there is significant savings in the electrical energy required to condition the outside air where air cleaning is provided.

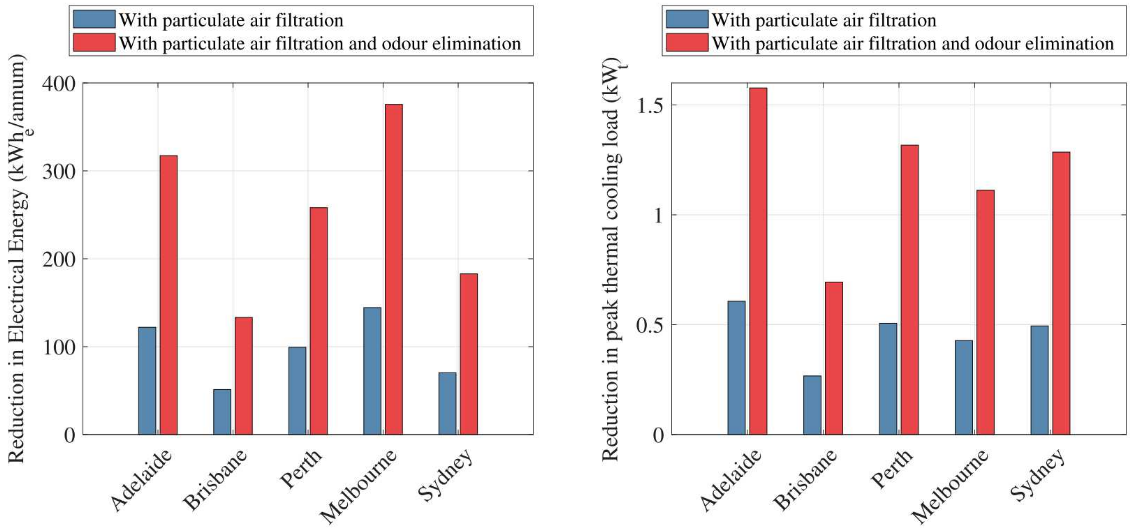

Figure 4: The reduction in annual electrical energy consumption by the HVAC system in kWh$_e$/annum (left) together with the reduction in HVAC system peak thermal cooling load in kW$_t$ (right) due to the use of air cleaning in the return air duct for five major cities across Australia.

Figure 4 presents the estimated reduction in annual electrical energy consumption as an absolute value (kWh$_e$) due to the use of air cleaning within the return air stream. Also provided is the reduction in peak thermal cooling load of the HVAC system due to the use of air cleaning. The results here show that with the PSS employed as a particulate air filter only, a savings in energy of 51.2 to 144.5 kWh per annum can be achieved, depending on the climate. This increases to an energy saving of 133.2 kWh to 375.6 kWh per annum for cases where the PSS is also employed as an odour eliminating device.

Here it should be noted that the present analysis conservatively assumes that the efficiency of the PSS to remove particles and odours is 80%. With this efficiency, the PSS needs to only filter out a maximum of 82 L/s (approximately 9.2%) of the return air. This flow rate is lower than the maximum rated flow rate of a single Plasma Shield model MMD600 unit. Therefore, there is a possibility that a single PSS unit may be able to serve multiple zones simultaneously (as discussed in Section 2.2.3), which would further result in increased energy savings. For example, in the current case study, configuring the PSS to operate at 95% efficiency would allow a single MMD600 Plasma Shield unit to serve 3 zones identical to the one analysed here, which in turn would result in a threefold increase in energy savings per unit.

The results also show that the utilisation of the PSS would significantly reduce the peak thermal cooling load by 0.27 to 0.61 kW$_t$ for the case where the PSS is configured as a particulate filter, or by 0.69 to 1.58 kW$_t$ for the case where the PSS also operates as an odour eliminator. This reduction in peak load not only reduces the size (and hence the capital cost) of the thermal plant, but also reduces the peak electrical demand of the building. As the HVAC system is typically a major contributor of a buildings peak electrical demand, the utilisation of the PSS would potentially significantly reduce the cost of peak demand of a building.

The results for Adelaide are summarised in Table 3 below.

*Table 3: Summary of results for the simplified case study of a single zone office in Adelaide. * Assuming the entire return air is cleaned by PSS. ** Assuming a PSS efficiency of 80%. *** Based on actual peak outdoor temperatures, not design outdoor temperatures. Note that here the units W_e and W_t refer to Watt (electric) and Watt (thermal) respectively.*

	Without PSS	PSS as Particulate Filter Only	PSS as Odour Eliminator
Flow Rates			
Supply air flow rate		9 L/s per m^2	
Introduced outside air flow rate	1 L/s per m^2	0.75 L/s per m^2	0.35 L/s per m^2
Minimum filter efficiency required*	-	3.0%	7.4%
Air flow rate through PSS**	-	0.3125 L/s per m^2	0.8125 L/s per m^2
Fraction of return air required to be serviced by PSS**	-	3.7%	9.2%
Energy Consumption			
Annual reduction in HVAC energy consumption for Adelaide	-	1.22 kWh_e/year per m^2	3.17 kWh_e/year per m^2
Peak Loads			
Reduction in peak cooling load of HVAC system for Adelaide***	-	6.1 W_t per m^2	15.8 W_t per m^2
Reduction in peak electrical load of HVAC system for Adelaide	-	1.7 W_e per m^2	4.5 W_e per m^2

2.3 Further Opportunities

As stated in the case study above, the maximum flow rate through the PSS was 81 L/s, which is below the maximum capacity of the model MMD 600 PSS unit. Therefore, there is potential to use a single PSS to serve multiple zones simultaneously, which would increase the energy savings of the HVAC system with a negligible increase in PSS energy consumption.

Furthermore, since the standards specify an absolute minimum value of introduced outside air flow rate with the use of air cleaning devices (i.e. 7.5 L/s per person with particulate filtration, and 2.5 L/s per person with additional odour treatment), a bigger proportion of HVAC energy savings can be realised in occupancy zones which require high effective outside air flow rates, such as delivery and operating rooms, hairdressers and industrial settings where occupants have high activity levels.

3 Rating Schemes

3.1 Green Star

The Green Building Council of Australia (GBCA) administers the Green Star rating scheme in Australia which aims to promote sustainable design of the built environment. It is a holistic rating tool that takes into account multiple factors that can contribute to a building's sustainability, with points awarded across multiple categories and sub-categories.

At the time of writing Green Star includes four different rating tools for different types of projects, namely, Green Star – Communities, Green Star – Design & As Built, Green Star – Interiors and Green Star – Performance. This report focusses on the Design & As Built tool (version 2), as it is the tool most commonly used for new and refurbished base building projects. The Design & As Built tool (v2) assesses a building's rating based on 9 categories:

1) Management (14 points)
2) Indoor environment quality (17 points)
3) Energy (22 points)
4) Transport (10 points)
5) Water (12 points)
6) Materials (14 points)
7) Land use and ecology (6 points)
8) Emissions (5 points)
9) Innovation (an additional up to 10 points)

Each category includes multiple sub-categories (called "Credits") where points are awarded. Green Star only provides a certified rating for 4-star, 5-star and 6-star projects, with the points required for each rating as follows:

1) 45 – 59% = 4 star
2) 60 – 74% = 5 star
3) 75% and above = 6 star

The categories most relevant to the usage of the PSS are indoor environment quality, energy and innovation. These are discussed in more detail below.

3.1.1 Indoor Environment Quality - Provision of Outside Air

This credit awards points for projects where the outside air flow rates exceed the minimum requirements as required by AS 1668.2 – 2012:

- 1 point is awarded where the outside air flow rates exceed the minimum requirements by 50%
- 2 points are awarded where the outside air flow rates exceed the minimum requirements by 100%

The PSS clearly has a role to play in this credit as its employment as an air cleaning device (as outlined in Section 2) will significantly reduce the minimum required air flow rates according to AS 1668.2 – 2012. That is, by reducing the minimum outside air requirements to meet the Standards, this will make it easier to achieve points for *exceeding* the minimum outside air flow rates.

3.1.2 Energy – Greenhouse Gas Emissions

The Green Star scheme provides significant amount of points for a reduction in ongoing greenhouse gas emissions due to the building's energy consumption. This credit has five different methods in which to demonstrate a reduction in greenhouse gas emissions, with the most points awarded if the project demonstrates that it can reduce energy consumption compared to an average building (either using a NABERS rating or using Green Star's reference building. 16 points are provided for a 100% reduction in greenhouse gas emissions, with points awarded on a continuous (pro-rata) scale for reductions less than 100%.

As shown in Section 2, utilisation of the PSS will reduce the HVAC energy consumption be allowing the minimum introduced outside air to be decreased. While the employment of the PSS will contribute towards an energy and greenhouse gas reduction, the magnitude of the energy savings, on the order of 0.3% to 2.3% of the total HVAC system energy, is relatively modest. Thus, it is unlikely that the PSS will be able to contribute to achieving points in this category on its own.

3.1.3 Energy – Peak Electricity Demand Reduction

Green Star awards up to 2 points where a project can demonstrate that it reduces peak electricity demand relative to a reference building, with 1 point awarded for a 20% reduction, and 2 points awarded for a 30% reduction.

The PSS will be able to directly contribute towards this credit as its employment will result in a reduction in the peak load of the HVAC system, which is a major contributor of a buildings overall peak electrical demand. While the magnitude of reduction depends on project and conditions, the simplified model estimates a savings up to 12.5% of the peak demand of the HVAC system. Assuming the peak demand of the HVAC system accounts for 50% of the building's peak demand, the resultant reduction in overall building peak electricity demand through using the PSS is about 6.3%, which in itself is insufficient to be awarded points. However, the utilisation of the PSS will partially contribute to points in this category as it can be combined with other methods to reduce peak demand.

3.1.4 Innovation

The Green Star scheme awards up to 10 points if the project can demonstrate a range of innovations that make the project stand out from other typical buildings. These points are typically challenging to obtain, however, Green Star does provide 1 point where a technology that is considered as innovative is utilised to improve on benchmarks or best practices. It could potentially be argued that the utilisation of Plasma Shield's novel PSS system to improve air quality and reduce the requirements of introduced outside air into the building would constitute the use of an innovative technology, resulting in the award of 1 point.

3.2 NABERS (Indoor Environment)

The NABERS for indoor environments of office spaces is an Australia-wide scheme managed by the New South Wales Department of Planning, Industry and Environment. This scheme is specific to office buildings and administered alongside NABERS energy, water ratings and waste ratings, which may be further applied to other types of buildings including shopping centres, apartment buildings, hospitals and hotels. The NABERS rating scheme is a six star scale benchmark relative to 12 months of data from comparable buildings where:

- 3 stars indicates "Market average building performance"
- 6 stars indicates "Market leading building performance"

Ratings are assessed by accredited assessors although NABERS provides an online tool for indicative results, although these cannot be promoted or published. In the case of indoor air quality, components of the NABERS assessment may be used for fulfilment or partial fulfilment of features in the WELL rating scheme.

The PSS provides a direct contribution towards the improvement of indoor air quality, although there would be a contribution to the NABERS energy rating through reducing the annual electricity consumption of the building.

The NABERS (Indoor Environment) scheme provides three different ratings based on the performance of the building from the perspective of:

- Building owners and managers (Base Building rating): for assessing centralised systems such as HVAC, building services and cleaning
- Tenants and occupiers (Tenancy): relevant to occupants in rating office fit-outs
- Whole Building ratings for organisations who both manage and occupy office space or entire buildings.

Each of these categories is subdivided into a combination of five parameters:

1) Thermal services
2) Indoor air quality
3) Acoustic comfort
4) Lighting
5) Office layout.

In the case of a Base Building, the rating is assessed based on a combination of thermal services (40%), indoor air quality (40%) and acoustic comfort (20%). Both Base Building and Tenancy ratings assign a 40% to indoor air quality, although the weightings of individual measurements are not identical. Indoor air quality has a weighting of 30% for a Whole Building. Table 4 summarises these values and provides the breakdown of indoor quality measurements and their weightings for each rating type.

Table 4: NABERS indoor air quality metrics for office buildings

	Base Building	**Tenancy**	**Whole Building**
Contribution of indoor air quality to star rating (overall)	**40 %**	**40 %**	**30 %**
Occupant air quality satisfaction survey	-	50 %	50 %
Ventilation effectiveness (CO_2)	55 %	20 %	20 %
Particulate matter (PM_{10})	30 %	10 %	10 %
Formaldehyde	-	10 %	10 %
Total volatile organic compounds (TVOCS)	-	10 %	5 %
Carbon monoxide (CO)	15 %	-	5 %

In these assessments, PM_{10} concentrations ($\mu g/m^3$) should be measured twice in one day, once in the morning and once in the afternoon, for 5 minutes at each sampling location using real-time monitoring with calibrated equipment having a specified minimum range, resolution and accuracy. Locations and measurement times vary depending on whether ratings are for the Base Building only, or for Whole Building or Tenancy ratings.

With regards to assessment for a Base Building, the PSS would contribute predominantly to the reduction of PM_{10} contributing:

- Base Building: 12% of total rating
- Tenancy: 4% of total rating
- Whole Building: 3% of total rating

Additional reductions in formaldehyde and TVOCS (beyond the scope of this report) would also contribute to Tenancy and Whole Building ratings. These are sampled in the morning only for 5 minutes each in locations related to the occupants and measured in ppm. Similarly, the NABERS ratings rules specifies minimum requirements for range and resolution, and TVOC ionisation calibration. The total potential impact of the PSS to NABERS indoor environment ratings (including PM_{10}, formaldehyde and TVOC reductions) are therefore:

- Base Building: 12% of total rating
- Tenancy: 12% of total rating
- Whole Building: 7.5% of total rating

3.3 WELL Rating

The WELL rating scheme is an international scheme that is administered by the International WELL Building Institute (IWBI). It is a scheme that focusses on the design of internal spaces and buildings for the improvement of human health and well-being. The scheme is a points-based system divided into a range of categories (called "concepts"), each of which have their own sub-categories. The points and categories based on scientifically-backed evidence, with the scheme being a performance based system, which must be verified with on-site testing by an authorised performance testing agent. A recertification process needs to be undertaken every 3 years to maintain the rating.

The current version of the tool is the WELL Building Standard version 2 (WELL v2), which has 10 categories. Within these categories there are 122 sub-categories, some of which provide points while others specify pre-conditions (i.e. minimum requirements to achieve a rating). The ten categories are:

1) Air
2) Water
3) Nourishment
4) Light
5) Movement
6) Thermal comfort
7) Sound
8) Materials
9) Mind
10) Community

There is also a category called "Innovation" which provides additional points where the project can demonstrate innovation or where it can demonstrate that it exceeds the requirements set out by the WELL rating scheme. There can be no more than 12 points per category, and a maximum of 100 points in total.

The rating scheme has four levels, namely Bronze, Silver, Gold and Platinum, with the amount of points required for the level summarised in Table 5.

The categories most relevant to the usage and employment of the PSS are the "Air" and "Innovation" categories, as outlined in more detail below.

Table 5: Points required to achieve the four different WELL Certification levels

Total points required	Min points per category	WELL Certification
40 points	0	Bronze
50 points	1	Silver
60 points	2	Gold
80 points	3	Platinum

3.3.1 Air

The “Air” category has three sub-categories in which the PSS may play a role, namely:

1) A01 Air Quality
2) A04 Construction Pollution Management
3) A05 Enhanced Air Quality
4) A06 Enhanced Ventilation Design
5) A12 Air Filtration

3.3.1.1 A01 Air Quality

For the A01 Air Quality sub-category, it is a pre-condition that the project achieve one of the following (depending on the ambient conditions)

- Option 1: Acceptable thresholds
    - Achieve <15 $\mu g/m^3$ of PM2.5 and <50 $\mu g/m^3$ of PM10 within the internal occupied space
- Option 2: Modified thresholds in polluted regions, for projects where the annual average outdoor PM2.5 level is >35 $\mu g/m^3$
    - Achieve <25 $\mu g/m^3$ of PM2.5 and <50 $\mu g/m^3$ of PM10 within the internal occupied space
    - Projects using this option will be limited to a WELL certification of Gold or lower
- Option 3: Dynamic thresholds in polluted regions, for projects where the annual average outdoor PM2.5 level is >35 $\mu g/m^3$
    - Indoor PM2.5 and PM10 levels need to be limited to <30% of the corresponding outdoor average levels from the past 24 to 48 hours (on the day the performance testing is conducted)
    - Projects using this option will be limited to a WELL certification of Silver or lower

Given the need to limit indoor PM2.5 and PM10 levels above is a pre-condition, the PSS will have a significant role to play in ensuring projects obtain any level of WELL certification. Also, acknowledging that PM2.5 particles are significantly more difficult to filter from the air than larger PM10 particles, it is important to note that to achieve a WELL Platinum rating, the levels of indoor PM2.5 need to be maintained at below 15 $\mu g/m^3$, regardless of outdoor conditions and the potential for indoor sources of PM2.5 (e.g. wear of dry-wall and cement/concrete). Therefore, the potential of the PSS to have an impact in this category is very significant, particularly for projects in polluted regions, given PSS’s efficiency in reducing PM2.5 can be well in excess of 95%.

It should also be noted that this sub-category also includes indoor thresholds for VOCs, either thresholds for individual VOCs, including Benzene (<10 $\mu g/m^3$), Formaldehyde (<50 $\mu g/m^3$) and Toluene (<300 $\mu g/m^3$), or a global threshold for all VOCs (<500 $\mu g/m^3$), the latter which needs to be continuously monitored. The sub-category also includes limits for ozone (<100 $\mu g/m^3$). Therefore, the PSS may potentially have a role to play in ensuring these thresholds are met, while Plasma Shield needs to be able to demonstrate that the PSS does not increase ozone levels past the threshold.

3.3.1.2 A04 Construction Pollution Management

This category includes a range of pre-conditions outlining the management of pollutants during the construction phase of the project. One of these requirements states that a “media filter” with a PM10 removal efficiency of at least 70% must be used in the return air duct of the conditioning system for any construction work after the project has been registered for certification.

While it is unclear if the requirement strictly is limited to porous media filters or if other forms of filtration is allowed, the intent of the category suggests that the PSS (which has a >70% efficiency in PM10 removal) should be able to meet this need.

3.3.1.3 A05 Enhanced Air Quality

This sub-category awards points for projects which exceed the minimum requirements for air quality. The points awarded for a reduction in indoor PM levels are:

- 1 point if indoor conditions are limited to <12 μg/m^3 of PM2.5 and <30 μg/m^3 of PM10
- 2 points if indoor conditions are limited to <10 μg/m^3 of PM2.5 and <20 μg/m^3 of PM10

As per the discussion in Section 3.3.1.1, the PSS can potentially have a significant role in ensuring projects not only meet the minimum pre-conditions, but also in ensuring that projects obtain the 2 points on offer for enhanced air quality due to PM reduction. While a prediction of the actual indoor PM levels for projects is not possible given that each project and each region is different, an estimation of the efficiency of filtration required to achieve maximum points can be obtained by conservatively assuming that the extreme case where the supply air (a combination of outside air and the return air) PM2.5 level is 100 μg/m^3 (for context, the highest PM2.5 level for any country in 2019 was 83.3 μg/m^3, according to the OECD). In this case, to achieve 2 points in this category would require a filter efficiency of 90% (PM2.5), which is still significantly lower than the typical PSS efficiency. That is, it is likely that projects employing the PSS will be able to achieve the maximum 2 points on offer in this category.

Note that this category also includes an additional 1 point for reduction in VOCs below the minimum threshold. As reduction in VOCs are outside the scope of the current report, this will not be discussed in detail here.

3.3.1.4 A06 Enhanced Ventilation Design

In this category, points are awarded if the outdoor air flow rates supplied to the occupied space exceeds the minimum requirements set by AS 1668.2 – 2012 (or the equivalent in the country where the project is located) by 30% (1 point) or 60% (2 points).

The PSS may play an indirect role in a project achieving these points as the employment of the PSS as an air cleaning device may reduce the minimum outside air requirements, as discussed in Section 2. That is, by reducing the minimum outside air requirements to meet AS 1668.2 – 2012, this will make it easier to achieve points for *exceeding* the minimum outside air flow rates. For example, consider a mechanically ventilated which is required to supply a minimum of 10 L/s per person. Employing the PSS as an air cleaning device (as discussed in Section 2) may allow the minimum OA requirements to be reduced to 7.5 L/s per person. To achieve 1 point in this WELL category, the OA flow rates would need to be increased by 30%, i.e., 1.3 × 7.5 L/s = 9.75 L/s per person, which is less than the system without the PSS. That is, by employing the PSS, the project could potentially gain points from this category without even needing to increase the OA flow rates (relative to the case without the PSS).

3.3.1.5 A12 Air Filtration

One point is awarded if a suitably efficient "media filter" is used to filter the outside air, according to the following requirements:

- If the annual average outdoor PM2.5 level is ≤ 23 μg/m^3, then the filter must have a minimum PM2.5 removal efficiency of ≥ 80%
- If the annual average outdoor PM2.5 level is 24 - 39 μg/m^3, then the filter must have a minimum PM2.5 removal efficiency of ≥ 90%
- If the annual average outdoor PM2.5 level is ≥ 40 μg/m^3, then the filter must have a minimum PM2.5 removal efficiency of ≥95%

Given that the PSS has a PM2.5 removal efficiency in excess of 99.7% (depending on configuration), the PSS will potentially provide the points in this category directly. However, the project team will have to request for an alternative interpretation to allow the PSS to be considered as a "media filter".

3.3.2 Innovation

The WELL rating scheme also provides up to 10 points for a number of possible sub-categories where the project can demonstrate innovation. The sub-category more relevant to the use of the PSS is I05 Green Building Rating Scheme.

3.3.2.1 I05 Green Building Rating Scheme

The WELL tool provides 5 points for any project which is also accredited by an appropriate Green Rating Scheme (list of acceptable green rating schemes provided on the WELL website). For Australia, the appropriate green rating scheme is GBCA's Green Star scheme. The use of the PSS can therefore indirectly contribute to achieving 5 points in this category by facilitating the project from achieving a Green Star rating (as discussed in Section 3.1).

Table 6: Summary of categories and their respective points where the PSS may contribute under the Green Star Design & As Built v2 and WELL v2 rating schemes

Category	Points Relevant to PSS Application	Description	Potential Role of PSS
Green Star Design & As Built v2 Rating Scheme			
9.2 Provision of Outside Air	Up to 2 points	• 1 point is awarded where the outside air flow rates exceed the minimum requirements set out by AS 1668.2 by 50% • 2 points are awarded where the outside air flow rates exceed the minimum requirements set out by AS 1668.2 by 100%	PSS has an indirect role in achieving these points, as the PSS may be able to reduce the minimum outside air requirements (as discussed in Section 2), thus making it easier for the project to achieve these points.
15 Greenhouse Gas Emissions	Up to 1 point	• Up to 16 points awarded for a reduction in green house gas emissions due to energy consumption of the building relative to a reference building • 16 points awarded for a 100% reduction, with points awarded on a pro-rata basis for reductions below 100%	The PSS has a minor role to play by allowing a reduction in the minimum outside air that is required to be introduced into the conditioned space. This, in turn will result in a reduction in energy consumption, as outlined in Section 2. However, this energy reduction is not likely to be sufficient to be awarded any points in itself, and therefore the PSS can only partially contribute to this credit.
16 Peak Electricity Demand Reduction	Up to 2 points	• 1 point for a reduction in peak electricity demand by 20% relative to a reference building • 2 points for a reduction in peak electricity demand by 30% relative to a reference building	The reduction in the minimum outside air requirements due the employment of the PSS will also result in a reduction in peak electricity demand of the HVAC plant. While this reduction is not expected to be sufficient to achieve the points on offer by itself, it can be combined with other mechanisms of

			peak demand reduction to obtain points in this credit.
30A Innovative Technology or Processes	1 point	• 1 point is awarded if the project demonstrates use of innovative technologies that is to improve on benchmarks or best practices	It could potentially be argued that the utilisation of the novel PSS comprises an innovative technology that both improves upon indoor air quality beyond current best practices while also allowing a reduction in the minimum require outside air flow rates.
WELL v2 Rating Scheme			

A01 Air Quality	Pre-condition	• Option 1:
		  ○ Achieve <15 $\mu g/m^3$ of PM2.5 and <50 $\mu g/m^3$ of PM10 within the internal occupied space
		
		• Option 2 (Gold or lower): For projects where the annual average outdoor PM2.5 level is >35 $\mu g/m^3$
		  ○ Achieve <25 $\mu g/m^3$ of PM2.5 and <50 $\mu g/m^3$ of PM10 within the internal occupied space
		
		• Option 3: Dynamic thresholds in polluted regions, for projects where the annual average outdoor PM2.5 level is >35 $\mu g/m^3$
		  ○ Indoor PM2.5 and PM10 levels need to be limited to <30% of the corresponding outdoor average levels from the past 24 to 48 hours (on the day the performance testing is conducted)
			The PSS has a strong role to play in this category, given the need to limit indoor PM2.5 levels.
			
			In particular, the PSS has the potential to play a significant role in projects located in highly polluted regions, or within indoor environments where PM2.5 generation is expected, as the threshold to achieve a Platinum rating remains constant regardless of outdoor and indoor conditions.

A04 Construction Pollution Management	Pre-condition	• Among other requirements, a media filter with a PM10 removal efficiency of at least 70% must be used in the return air duct of the conditioning system for any construction work after the project has been registered for certification.	PSS may be able to directly meet this need, but a request for an "alternative" interpretation may be required to allow PSS be classed as a "media filter".
A05 Enhanced Air Quality	Up to 2 Points	• 1 point if indoor conditions are limited to <12 $\mu g/m^3$ of PM2.5 and <30 $\mu g/m^3$ of PM10	Given the particle removal efficiency of the PSS can exceed 99.7% (depending on configuration), it is

		• 2 points if indoor conditions are limited to <10 µg/m^3 of PM2.5 and <20 µg/m^3 of PM10	likely that projects employing the PSS to filter outside air will be able to achieve 2 points in this category.
A06 Enhanced Ventilation Design	Up to 2 points	• 1 point awarded if outside air flow rates exceed minimum requirements by 30% • 2 points awarded if outside air flow rates exceed minimum requirements by 60%	PSS has an indirect role in achieving these points, as the PSS may be able to reduce the minimum outside air requirements (as discussed in Section 2), thus making it easier for the project to achieve these points.
A12 Air Filtration	1 point	Install "media filters" to filter the outside air to the following efficiencies: • If the annual average outdoor PM2.5 level is ≤ 23 µg/m^3, then the filter must have a minimum PM2.5 removal efficiency of ≥ 80% • If the annual average outdoor PM2.5 level is 24 – 39 µg/m^3, then the filter must have a minimum PM2.5 removal efficiency of ≥ 90% • If the annual average outdoor PM2.5 level is ≥ 40 µg/m^3, then the filter must have a minimum PM2.5 removal efficiency of ≥95%	Given the PSS has a PM2.5 removal efficiency in excess of 99%, employment of the PSS in a project may result in achieving the 1 point on offer in this category if the WELL reviewers can be convinced that the PSS be categorised as a "media filter".
I05 Green Building Rating System	5 points	• 5 points awarded to projects which also have an accredited green building rating from any of the certified Green Building Rating schemes (e.g. GBCA's Green Star)	The PSS can indirectly contribute to achieving these points by facilitating building projects in achieve a green rating scheme (as discussed in Section 3.1)