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Upgrading Windows With Window Films

Achieve increased building energy-efficiency with installation of window films.

In recent years, there has been a global shift for buildings to become more environmentally sustainable and energy efficient. In Australia, there are national rating systems which are used to evaluate and compare these two metrics for commercial buildings and residential houses which are important not only for reducing our carbon footprint and improving building value, but also in reducing energy costs. This has building owners and homeowners looking for upgrades and retrofit options to improve the energy efficiency.

In this white paper, we look at how window films can be used to upgrade windows – in particular, to reduce the amount of solar energy transmitted through them. This improves the building envelope and places less demand on HVAC systems, leading to a more energy-efficient building and increased cost savings to the building owner or consumer.

What Are Window Films?

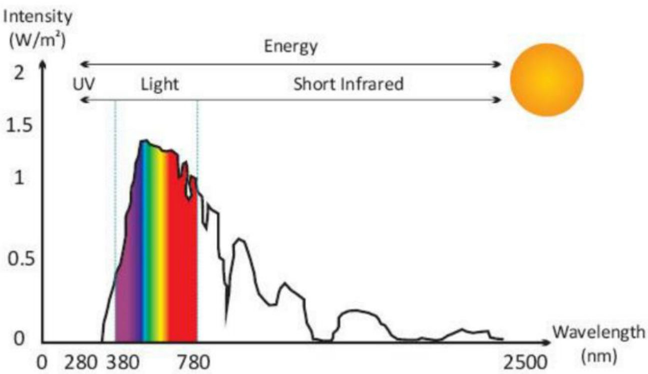
Typically made from polyethylene terephthalate (PET), window films can be used on the interior or exterior windows of automotive and buildings. They can contain different components such at metallized, ceramic, and an adhesive to bond to the glass. There are different types of window films which provide solutions for a variety of needs:

- To reduce the amount of solar heat entering the building.
- Occupancy comfort – reducing glare and temperature imbalances in a building, as well as improving occupant privacy with high reflectivity or architectural films.
- Blocking UV light, which slows the process of fading of furniture, carpet, etc. and protecting skin from UV rays.
- Improved building aesthetics – window films cover a range in levels of tint and reflectivity, depending on aesthetic preferences.
- Safety and security window films for anti-graffiti, blast and windstorm mitigation, human impact, and spontaneous glass breakage.

Some window films are a hybrid of sun control and safety film technologies which offer a combination of the above benefits into a single film.

How Can Window Films Reduce Solar Heat and Provide UV Protection?

To understand how window films work, let's first look at the solar spectrum. The energy from the sun that reaches the Earth's surface is comprised of approximately ~2% ultraviolet (UV) light, ~43% visible light, and ~53% infrared (IR) light [source]:

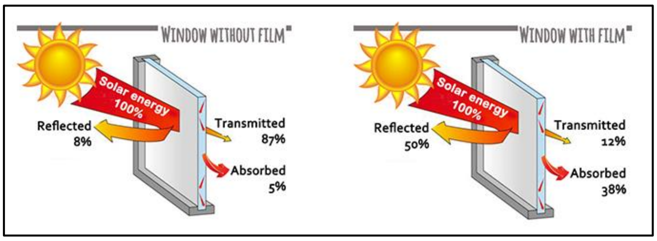


*Distribution of energy in the solar spectrum [*Tahouri, A. (2015). Evaluation of Windows and Energy Performance Case-Study: Colored Building, Faculty of Architecture (EMU)]

Most of the UV light emitted by the sun is absorbed by the Earth's atmosphere, but the small fraction remaining is destructive to our skin and is the largest contributing factor to fading of interior furnishings.

The visible spectrum is the portion of the sun's energy that we see and has the highest intensity of the spectrum. Finally, IR light makes up the largest portion which we do not see but feel it as heat.

When the sun hits a normal window, most of the energy is transmitted through to the inside of the building. The rest is either reflected outside or absorbed by the glass and then re-radiated outside and inside. Window films that are designed to reduce the amount of solar energy entering a home or building (also known as "sun control window films") work by blocking more than 99% of UV light, reducing/rejecting the amount of IR light entering the building, and reducing varying amounts of visible light entering the building depending on how dark the film is.



An example of the effect of a high-performing window film on a single pane window [https://www.wfaanz.org.au/about-window-film/]

A Need for More Energy Efficient Buildings and Homes

In early 2019, Victoria experienced power outages when temperatures exceeded 40°C in combination with high humidity drove up the demand for power due to extensive air conditioning use. Emergency energy reserves were drawn from neighbouring states and eventually power companies had to resort to load shedding (intentionally shutting off power or "brownouts") because demands were putting the entire system at risk. More than 200,000 customers were impacted and in some areas of the state homes were without power for up to two hours [1].

Generally, energy demand is higher during certain times of the day. This is usually between 4 and 8 P.M. when businesses and factories are still open, and people begin to arrive home from work and switch on their air conditioners, televisions, and other appliances. This is also reflected in the cost of energy, as the rates are higher during peak hours and lower during off-peak times:

Energy Retailer	Typical Peak Pricing	Typical Off-Peak Pricing
AGL	49c/KWh	13c/KWh
Origin	54c/KWh	14c/KWh
Energy Australia	54c/KWh	17/KWh

Figure 1: Rates from different energy provide plans on Ausgrid network in New South Wales, July 2020 [2].

Reducing energy demand in summer peak load periods is important not only for large electricity networks and utilities but can also significantly reduce costs/electricity bills for businesses and consumers.

Window Film - Optimizing buildings with Envelope Improvements

There are many energy conservation technologies available to help you reduce energy consumption, lower CO_2 emissions, and ultimately save money. It is essential not only to choose the right products, but also in the order in which to complete the facility upgrades to maximize the gain in energy efficiency and cost savings.

Commercial building owners usually jump straight to upgrading their HVAC system since it accounts for most of the energy costs in a commercial building. However, the thermal properties of the building envelope have a significant impact on the building energy performance, because a lot of energy is needed to compensate when heat transfers through it. If you create a more efficient building envelope prior to upgrading the HVAC system, like by enhancing the windows with sun control window film, you will maximise its efficiency and get the most out of your investment.

Residential homeowners may look at upgrading to more energy efficient appliances or using water more efficiently. However, as with commercial buildings, space conditioning is the largest end-use of energy in homes and window films are a passive system that can reduce the need for air conditioning.

How can Window Films Improve the Energy Efficiency of a Commercial Building or Home?

Windows are the single largest sources of unwanted heat gain transmitted into a building through solar energy. Windows make up a relatively small size (~20-30%) on an average commercial building envelope compared to the rest of its façade like walls and roofing but depending on the window type up to 87% of the sun's energy that hits the window is transmitted through as heat. In addition, HVAC systems are the largest portion of energy consumption in commercial buildings:

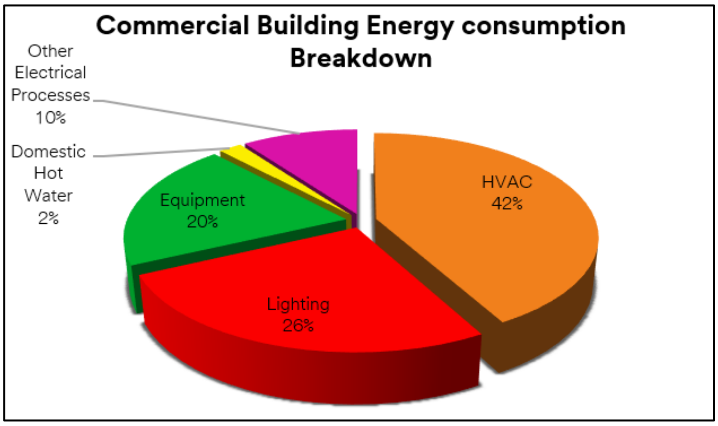


Figure 2: Shares of commercial building energy end use from 1999 - 2012 [3].

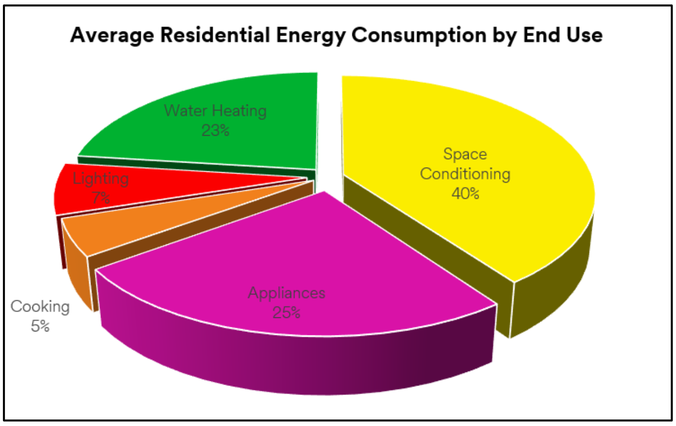


Figure 3: Proportions of total residential consumption by end use for Australian homes in 2014 [4].

Because windows make up a significant source of heat gain and HVAC systems are a major component of energy usage, upgrading the windows of a building can improve its energy efficiency.

CSIRO Study on the Impact of Window Film on Residential Homes

3M commissioned CSIRO to model the potential residential heating and cooling energy savings using a range of different 3M Sun Control Window Films across diverse climatic zones in Australia. The study used building simulation software AccuRate and two different residential house designs, a four-bedroom single-storey house and a two-storey townhouse to model the performance of different 3M Window Films. The house design, size, window glazing characteristics, heating and cooling systems used in the AccuRate simulation software were selected to achieve a four-star NatHERS Energy efficiency rating, which was considered to be representative of medium perform homes found in Australian capital cities.

House Model	House Type	Wall Type	Storeys	Bedrooms	Floor Area (m^2)	Window to Floor Ratio (m^2)	Total Window Area (m^2)	Window Frame Types	Glazing Systems	
House 1	Detached	Cavity, Brick	1	4	299.4	0.15	40.52	Aluminium & Timber	4mm Clear	3M Sun Control Window Films #1-5
House 2	Semi-Detached	Cavity, Veneer	2	3	128.6	0.2	21.14	Aluminium & Timber	4mm Clear	3M Sun Control Window Films #1-5

Table 1: House model and glazing systems used in the CSIRO study.

CSIRO concluded that in temperate, warm and hot climate zones such as Perth, Sydney, Brisbane and Darwin, applying 3M Sun Control Window Films to clear glazing windows facing east, north and west may reduce the total heating and cooling energy requirement and its related energy costs. Depending on the space heating and cooling systems used, the total annual energy cost saving may be in the range of 10-20% by using some particular window films. Using average energy costs of $0.25/kWh for electricity and $0.018/MJ for natural gas, the potential annual savings for a four-bedroom single-storey home may be around $100 to $200 a year in temperate and warm climates and up to $450 a year in hot climates.

Where the 3M Sun Control Window Film most appropriate for the climatic zone was selected, the simulation results showed that a potential reduction of 10 - 30% in the energy required to cool the house during the hotter months may be attainable. Reducing the demand on the electricity grid during the hotter months is imperative as it reduces the potential for grid outages during the peak load periods.

The simulation results are indicative only and actual energy savings will vary based on the local climate, the design of house, orientation, glazing characteristics, HVAC efficiency, window to wall ratio and type of window film.

Climate Zone	Recommended Films	Cooling Energy Reduction
Brisbane E, N, W	AF 15, NV 25, PR 40	5 – 23%
Cooling and Heating Zone	**Total Energy Reduction**	**Cooling Energy Reduction**
Sydney E, N, W	AF 15, NV 25, PR 40	6 – 28%
Perth E, N, W	AF 15, NV 25, PR 40	6 – 27%
Adelaide E, N, W	AF 15, NV 25, PR 40	5 – 24%
Heating Zone	**Total Energy Reduction**	**Cooling Energy Reduction**
Melbourne E, W	CM 50, PR 40, NV 25	5 – 31%
Hobart E, W	CM 50, PR 40, NV 25	8 – 50%
Canberra E, W	CM 50, PR 40, NV 25	6 – 41%

Figure 4: CSIRO simulation results for estimated cooling energy reductions with window films in specific Australian climate zones [5]. AccuRate was used for the simulations, which is the same software utilized by NatHERS (Nationwide House Energy Rating Scheme).

The technology of window films today can greatly improve performance of a window by rejecting up to 80% of solar energy, and this is often at less than half the cost of replacing windows or installing an additional pane. The Rawlinsons Construction Cost Guide 2019 found that the average installed cost of a reflective, high-performing window film was $78.75, compared to the average cost of a new double-pane window at $431.33/sqm [7].

Likewise, window films compare well against other types of energy efficiency improvements. A 2012 energy analysis report by ConSol examined the cost-effectiveness of window film applications on residential homes and commercial buildings in four climate zones in California. The study found that window films are more energy efficient and cost-effective to install on existing buildings than new furnaces, new air conditioning, installing more ceiling insulation, or by improving the sealing of the building envelope [6]:

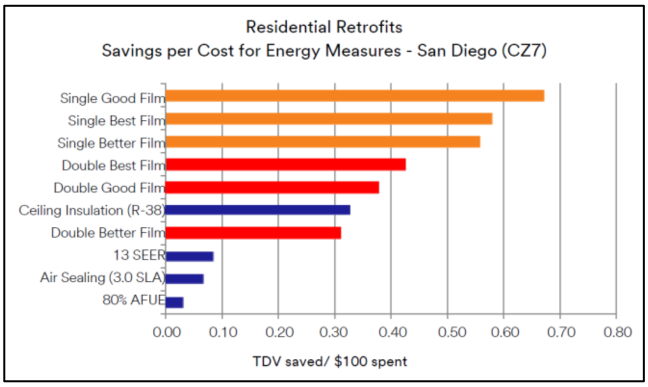


Figure 5: Savings per cost retrofit comparisons for a simulated residential home in San Diego, CA as part of the ConSol study [6].

A Cost-Effective Retrofit

Existing buildings seeking to improve the energy efficiency of their glazing/window system may consider one of the following choices:

- Replacing existing windows with double or triple pane IGU
- Adding an additional pane of glass to the windows
- Retrofitting with window film

Compared to the former options, window films represent a significant opportunity for cost-effective savings with the fastest payback.

Existing Offices in San Diego
Table 15: San Diego (C27) ROI for Existing Offices with Single Pane Glass

SINGLE PANE	No Film	Good	Better	Best
Total Electricity (MWh)	5, 969	5, 655	5, 366	5, 030
Total Gas (Therms)	12, 036	10, 790	9, 577	7, 982
Energy Cost	$907, 425	$859, 045	$814, 443	$762, 529
Annual Savings	-	$48, 380	$92, 981	$144, 896
Cost of Film	-	$249, 515 $434, 176 $598, 837	$249, 515 $424, 176 $598, 837	$249, 515 $424, 176 $598, 837
Annual ROI $5 film	-	19%	37%	58%
Annual ROI $8.50 film	-	11%	22%	34%
Annual ROI $12 film	-	8%	16%	24%
Simple Payback $5 Film	-	5.16	2.68	1.72
Simple Payback $8.5 Film	-	8.77	4.56	2.93
Simple Payback $12 Film	-	12.38	6.44	4.13

Figure 6: Payback estimates for window film applications on an existing commercial building in San Diego, CA on single pane windows [6].

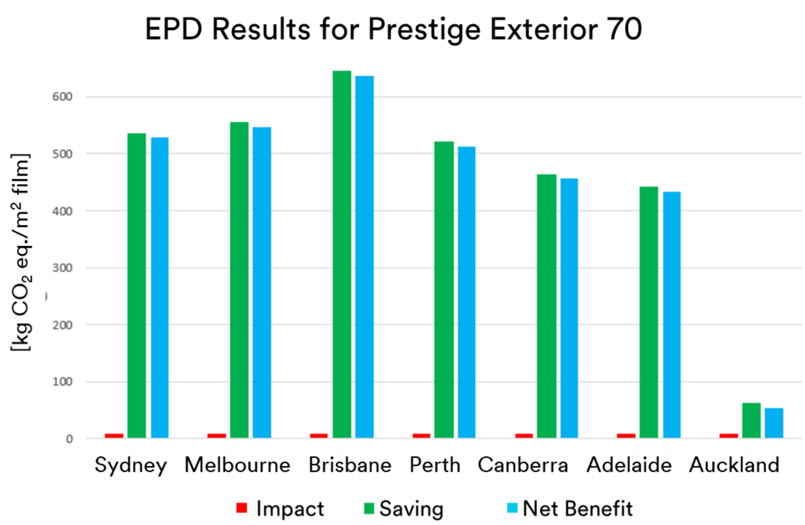
Environmental Impact of Window Film

Globally, there is a push for governments and companies to reduce the addition of greenhouse gases to the atmosphere towards net-zero. This has made the need for transparency of supply chains and communication of environmental properties increasingly important for product manufacturers. One way that this information can be communicated is through an Environmental Product Declaration (EPD). An EPD is a verified, transparent document that reports environmental impacts of a product based on a cradle-to-grave analysis in accordance with ISO 14025.

It allows consumers to compare products within the same category and choose which the one which has the least environmental impact. This information can be especially important for building owners when considering which products to use for building energy efficiency improvement projects, and EPDs may be used by project teams to obtain Green Star points.

3M recently completed a large EPD project to evaluate the impact of Prestige Window Film on carbon emissions and Water Depletion in 52 cities spread over 31 countries in Europe, Middle East & Africa, Asia, Oceania and the United States. For the project a 4-storey office building was used with 1858 m² conditioned space and 725 m² clear dual panes to which the 3M Prestige Window Film (PR70, PR70X or PR40X) is applied for a period of 10 or 15 years (film's warranted lifespan).

The EPDs, available online on the EPD International website (www.environdec.com), show that 3M Prestige Window Film in Australia and New Zealand can offer a significant carbon emissions and water depletion savings at a very small environmental cost. In Sydney, for example, Prestige 70 Exterior can lead to a net savings of over 500 kg CO_2 eq. per square metre of film after 10 years.



Government Efforts in Improving the Country's Energy Efficiency

Australia has implemented and adopted the NABERS system, which allows commercial building owners to measure and benchmark their environmental performance compared to similar buildings, as well as identify potential energy savings opportunities. It has been proven that window films can improve the SHGC of existing windows to reduce the overall load on the HVAC system and directly improve a building's NABERS rating. To date, NABERS has achieved 76% penetration in office buildings nationally with plans to expand to all major building types by 2024[8].

Similarly, the NatHERS program evaluates energy efficiency for residential houses and will extended to include existing homes by approximately mid-2021. As we discussed earlier, the average Australian household spends most of its energy use on heating and cooling. NatHERS promotes the benefits of increasing the thermal performance of houses through good insulation and passive solar design, and window films check both of those boxes.

The national and state governments have broader energy efficiency plans that window films can positively impact. For example, the National Energy Productivity Plan (NEPP) is a package of measures to improve Australia's energy productivity by 40% between 2015 and 2030, including ones that support better energy use in buildings [9]. In March 2020, the NSW Government announced "The Net Zero Plan" outlines a plan to reduce emission 35% by 2030 and eventually to reach net zero emissions by 2050 [10].

Summary

Window performance can have a significant impact on the building envelope's heat gain, and window films are a cost-effective retrofit that can substantially improve the windows' performance and lead to a more energy efficient building or home. By rejecting solar energy, especially during times of peak energy demand, window films can directly improve NABERS ratings, reduce demands on energy companies, lead to cost savings for consumers, and help the Australian government meet its energy reduction and climate targets.

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