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Review

# Self-cleaning glazing products: A state-of-the-art review and future research pathways

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ABSTRACT

Self-cleaning technology is used in a variety of products today, with glazing products being the foremost area of application. However, there are several self-cleaning technologies in use and their self-cleaning efficiency may be unclear. This study aims to give a comprehensive state-of-the-art review of the self-cleaning glazing products available on the market today and investigate methods for measuring the self-cleaning effect. Various future research pathways and opportunities for the self-cleaning products of tomorrow are also explored within this study, with emphasis on solar energy application areas such as daylight, solar radiation transmission, electrochromism, building integrated photovoltaics (BIPV), solar cell glazing and solar cells in general. Self-cleaning products from several manufacturers that utilize two different self-cleaning technologies of either photocatalytic hydrophilic or hydrophobic capability are presented. The photocatalytic hydrophilic products in question are self-cleaning glazing products ready-to-use when purchased, whilst the presented hydrophobic products are coatings that must be applied to existing glazing products in order to yield a water-repellent and self-cleaning surface. It is stated that the self-cleaning action of the photocatalytic hydrophilic products is evident through 25–30 years, even during dry spills, and that they are able to maintain a cleaner surface than ordinary untreated float glass. However, the self-cleaning action of hydrophobic-coated products is limited by a relatively short life expectancy of about 3–4 years, and their self-cleaning performance is found to be feeble compared to ordinary untreated float glass. Nonetheless, the potential for future use of both self-cleaning technologies are apparent, with focus on alternative application areas such as solar cells, BIPV and information display devices, which indeed could benefit from utilizing the self-cleaning technology. Visions for future self-cleaning products are also discussed, which combine self-cleaning abilities with photovoltaism and electrochromism, whereupon the applicability of the self-cleaning technology may be greatly increased.



**Contents**



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## 1. Introduction

Self-cleaning glazing is available as a thin-film outer layer on products as windows and doors; consequently, self-cleaning products are subjected to the ever-changing outdoor environment. Hence, knowledge of their ability to withstand dirtying and maintain a tolerable cleanliness and performance over time is of great importance. A standard scientific method to quantify the self-cleaning effect of these products would be helpful, especially when comparing various self-cleaning products, and considering the actual benefit by choosing a self-cleaning glazing product in preference to an ordinary product. Moreover, self-cleaning products require less maintenance, and are thereof both time- and money-saving in comparison with ordinary windows or doors, still there are certain characteristics of these products that may limit their use. To better understand the limitations and advantages of self-cleaning glazing products, this study examines what products are available on the market today, along with discussing their strengths and weaknesses, and outlining possible future research pathways and opportunities for self-cleaning technology.

A fully operational self-cleaning window, and large glazing structures, will be able to utilize and control much more of the solar radiation energy as no radiation is absorbed or reflected by any dirt on the glass surface, e.g. for daylight utilization, smart windows, building integrated photovoltaics (BIPV) as solar cell glazing and possible combinations of these. Hence, self-cleaning glazing products may lead to increased solar energy control and thus increased energy savings and user comfort.

The need for and the benefits from a standardized method to evaluate the performance of self-cleaning glazing products, has already been addressed through a research report initiated by several industrial parties in the European glass market [1]. This research report presented several work packages, with aims to understand; what contaminants affect the glazing products, the influences of the manufacturing process, the self-cleaning reaction phenomena at nano scale, and within that framework, present a possible measurement method as a proposal for standardization by CEN and ISO. This method is, among other factors, based on visual observations and haze measurements of contaminated self-cleaning specimens. The results of this study show that hydrophilic self-cleaning glass on average have a good self-cleaning effect. Hydrophobic glass, however, is observed and measured to have a considerably lower self-cleaning effect, even lower than ordinary clear float glass.

In an earlier study, performed by Chabas et al. [2] on the behavior of self-cleaning glass in an urban atmosphere, self-cleaning glass is found to have an evident self-cleaning effect, even when it is not subjected to water. The field study showed that particulate organic matter (POM) was destroyed by a percentage of 44–48% on the self-cleaning surface, and it was not observed any significant difference in effectiveness between glass specimens that were protected from rain and glass specimens that were not. However, the self-cleaning glasses had some remaining organic deposits, which were firmly bonded to the glass surface and were not washed off without human intervention. Moreover, another study, by Jelle et al. [3], emphasizes that some maintenance, due to fastened organic or inorganic dirt, will be necessary with self-cleaning products regardless of their self-cleaning nature, though maybe not as frequent as with ordinary windows. Consequently, the self-cleaning windows may therefore also have a possible positive environmental impact, as due to less cleaning the use of chemical cleaners is reduced accordingly, which otherwise might have been spilled into the ground.

The objective of this study is to attain a clear overview of the self-cleaning glazing products available today, to investigate methods for measuring the self-cleaning effect, and to explore various future research pathways and opportunities for the self-cleaning glazing products of tomorrow. To comply with these purposes, this study is divided into three parts. The first part suggests and investigates possible methods for measuring the cleaning effect of self-cleaning glazing products. The second part is a state-of-the-art review of all the large self-cleaning glazing manufacturers and their available products of today. The third and last part is a possibility study of the research and development being performed on the subject as of now, in addition to illustrate possible solutions and products for the future. The products in question in this study are mainly glass components and applications to such, e.g. windows and window treatment products. Nonetheless, the potential for self-cleaning surfaces in general, including ice and snow free surfaces, is huge. Therefore this study also encompasses various wall and roof surfaces, photovoltaic solar cells, solar thermal panels, cars, road signs, etc.

The presentation of the self-cleaning glazing products in the second part of this study includes a lot of information, like manufacturers, product names and various material properties, such as visible transmittance ($T_{vis}$), solar transmittance ($T_{sol}$), ultra violet (UV) transmittance ($T_{uv}$), solar reflectance ($R_{sol}$) and solar factor (SF), among others. The definitions and further details of these values may be found in Jelle and Gustavsen [4]. Furthermore, this study introduces a new performance term regarding self-cleaning glazing products, a self-cleaning factor (SCF), which is defined as a quantifiable measure of the self-cleaning efficiency.

In order to present all the information mentioned above, several tables are summarizing all this data, which for the most part is given in the main text. However, a more detailed tabulated description is given in the appendices. Several of the presented product properties are very important, even crucial, to evaluate and compare the self-cleaning glazing products. However, few manufacturers provide this kind of data, even though consumers and professionals need this information in order to consider and evaluate the use of the self-cleaning glazing products. Regardless of available information, the mentioned key product properties are given in the tables nonetheless, thus lacking data is seen as open spaces in the tables within this study. Hopefully, by