Assessing and Reducing F-GHGs
in the Electronics Supply Chain

March 2016

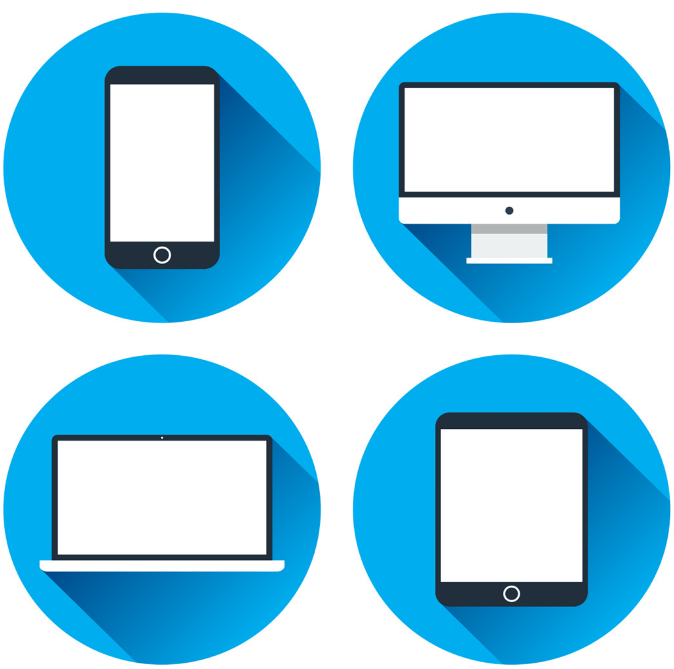
ELECTRONIC INDUSTRY CITIZENSHIP COALITION

OVERVIEW

Addressing the risks and challenges of climate change is a high priority for governments worldwide as evidenced by the recent COP 21 agreement in Paris. Companies have a critical role to play in addressing these risks and challenges by reducing emissions across their global supply chains.

The Electronic Industry Citizenship Coalition (EICC), the leading body addressing sustainability in the electronics industry supply chain, is planning a pilot program to reduce fluorinated gases (F-GHGs), a powerful type of greenhouse gas that is used during electronics manufacturing. Because if it is not measured, it cannot be managed, the first step is to assess the prevalence of these greenhouse gases in the supply chain. For the purposes of this report, we conducted what we believe is a first-of-its-kind survey among approximately 90 percent of the marketplace for liquid crystal display (LCD) panel manufacturers in our members' shared supply chain. These companies make panels for TVs, phones, cameras, notebooks, tablets, automotive and aerospace vehicles, medical devices, and some industrial displays.

Carbon dioxide (CO_2) is the most commonly known greenhouse gas (GHG), but there are six other types of GHGs recognized by the United Nations Framework on Climate Change Convention. These include methane, nitrous oxide, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3); the later four of which are referred to as F-GHGs. According to the Intergovernmental Panel on Climate Change 5th Assessment Report, CO_2 accounts for 76 percent of global emissions, methane and nitrous oxide contribute 22 percent, with the final 2 percent being F-GHGs.[1]



F-GHGs are mostly human-created, occurring in the natural world only in minute quantities. They generally have very high global warming potentials (GWPs) relative to other GHGs and possess long atmospheric lifetimes – in some cases, lasting thousands of years. Thus, small volumes have tremendous and lasting impacts on our climate. F-GHGs circumnavigate the globe through atmospheric currents and are removed once they are destroyed by sunlight in the far upper levels of the atmosphere.

Electronics manufacturing, which includes the manufacturing of semiconductors, photovoltaic cells, microelectromechanical systems, and liquid crystal display (LCD) panels, is one source of F-GHG emissions. Etching and chamber cleaning are the primary panel manufacturing processes that use F-GHGs, the climate impacts of which are largely unknown. F-GHGs are also used as heat transfer fluids to help cool equipment and are emitted as they evaporate. In these processes, the relevant F-GHGs are CF_4, SF_6, and NF_3 but may include others.

There are five main categories of fluorinated gases – hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), carbon tetrafluoride (CF_4), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3). To better understand how these fluorinated gases are used, the amounts used, what controls are in place, and the amounts emitted from manufacturing, the EICC conducted this study.

METHODOLOGY

The EICC collected data from seven companies, representing 29 different fabrication facilities (fabs) with various forms of emission control. Most companies reported emissions for a single fab[2], but others reported for five facilities and one company reported for 12 facilities.

We collected information about:

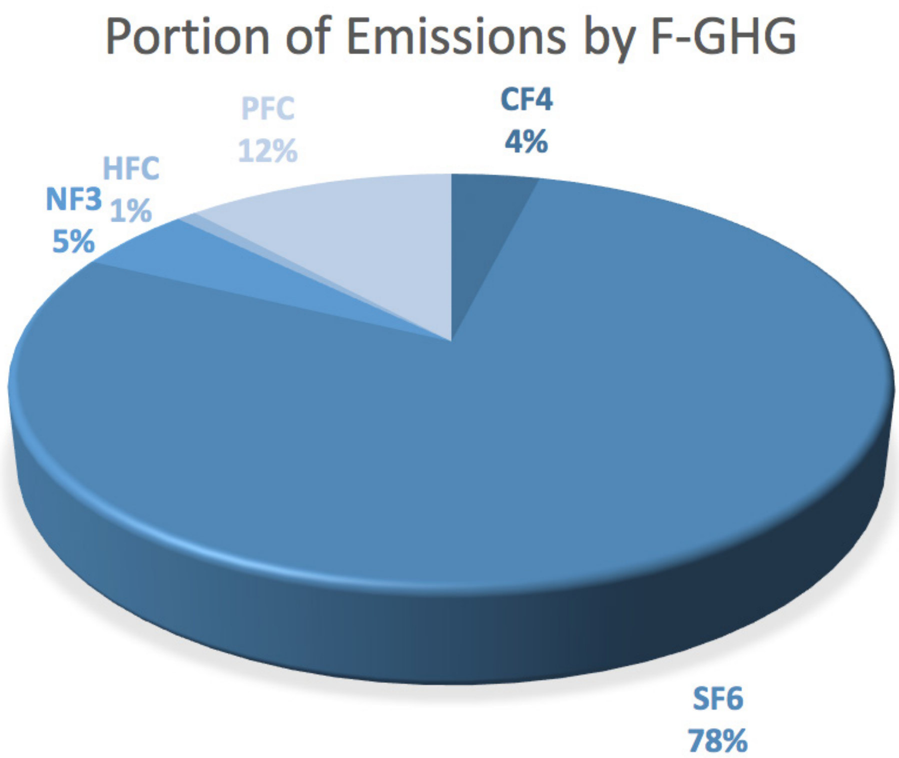
- The substrate size at each facility;
- CF_4, SF_6, NF_3, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and total GHG emissions;
- Percent of etching and chamber cleaning equipment with F-GHG abatement systems;
- Percent of F-GHGs recycled;
- F-GHG destruction or removal efficiency; and
- Total F-GHG emissions per square meter of panel manufactured in 2014.

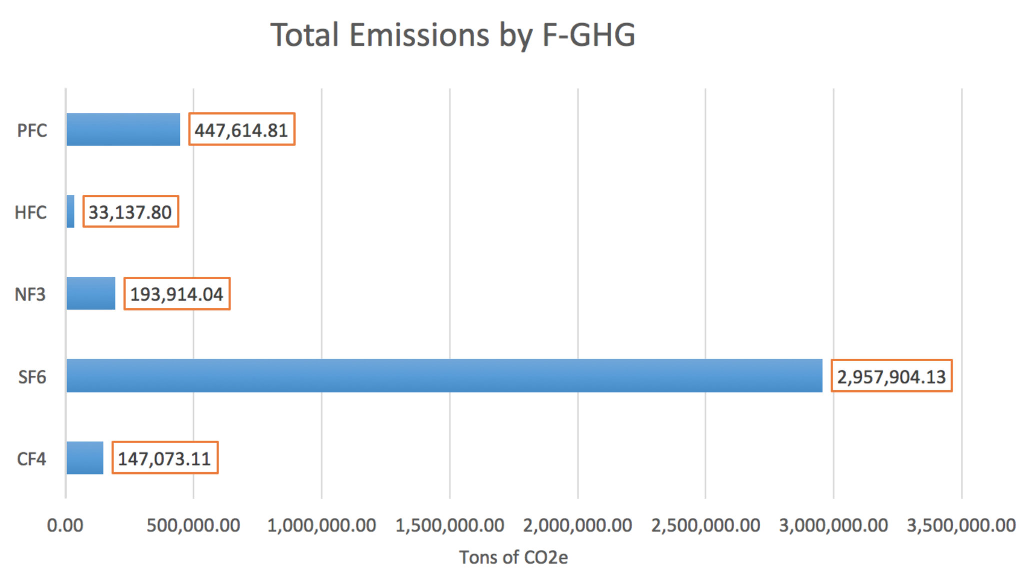
1 https://www.ipcc.ch/report/ar5/wg3/

2 However, there may have been some confusion in terms for facility, so for these purposes data is represented at a company-level unless otherwise indicated

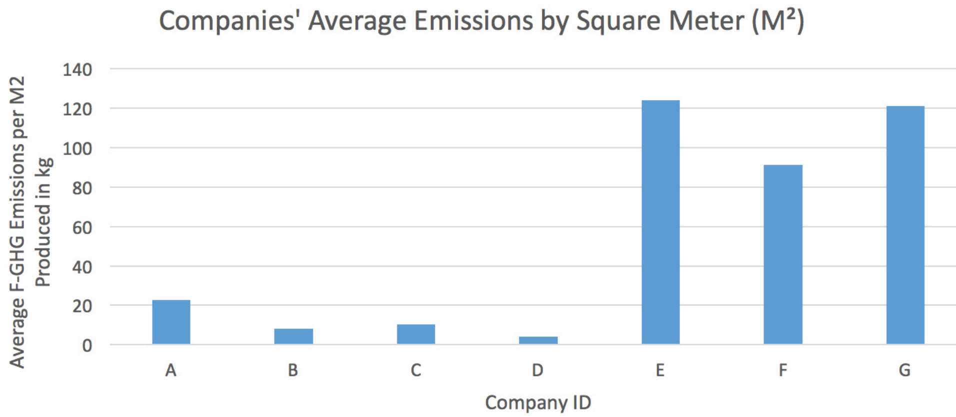
KEY FINDINGS

From the seven companies, our survey shows that 3,779,643.89 Metric tons of CO_2 equivalent (CO_2e) were emitted. Of those nearly 3.8 million tons, the majority was attributed to SF_6 – nearly 2.96 million tons of CO_2e. The next-highest emissions resulted from PFCs at 447,614.80 tons of CO_2e. That means that SF_6 accounted for more than six times the emissions of the next-highest F-GHG. Every company reported using SF_6 and NF_3, while HFCs were clearly the least emitted.

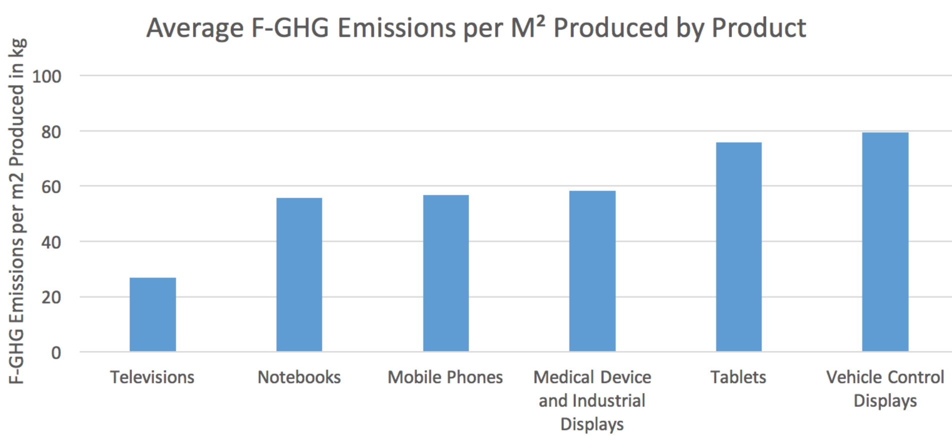




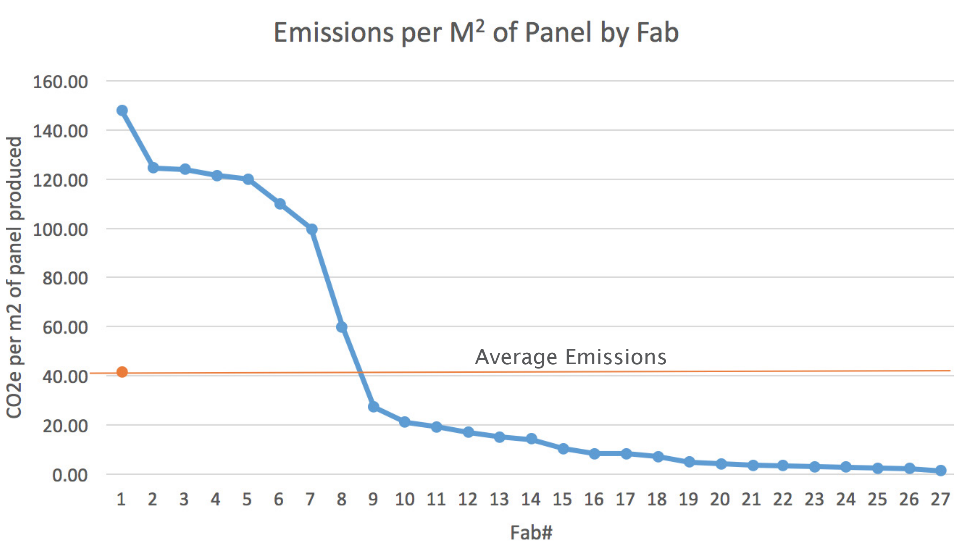
Of course, total emissions do not let us compare companies meaningfully. Some of these companies are much larger than others, both in terms of number of fabrication facilities (fabs) and production area, resulting in potentially higher total emissions. To help normalize the emissions data we looked at total F-GHG emissions per square meter (M^2) of panel a fab produced from January through December 2014. In doing so, a clear distinction appears. Four companies averaged far fewer emissions per M^2 across their fabs than three others. The lowest of those high-average emitters was more than quadruple the low four.



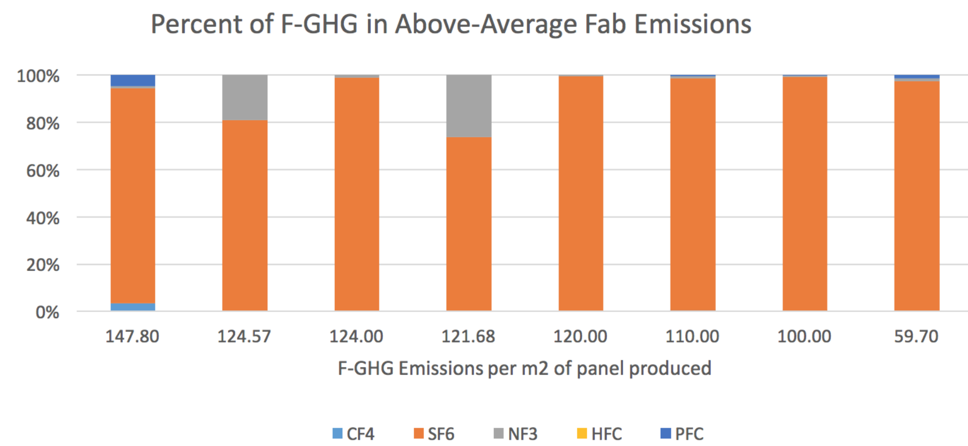
Clear distinctions in emissions by product are also seen. Every company and most fabs produced displays for more than one type of product. Therefore, the chart below shows an average emissions per M^2 of panel manufactured for the most common product types for which these panels are used, taking into account reported information from all companies.



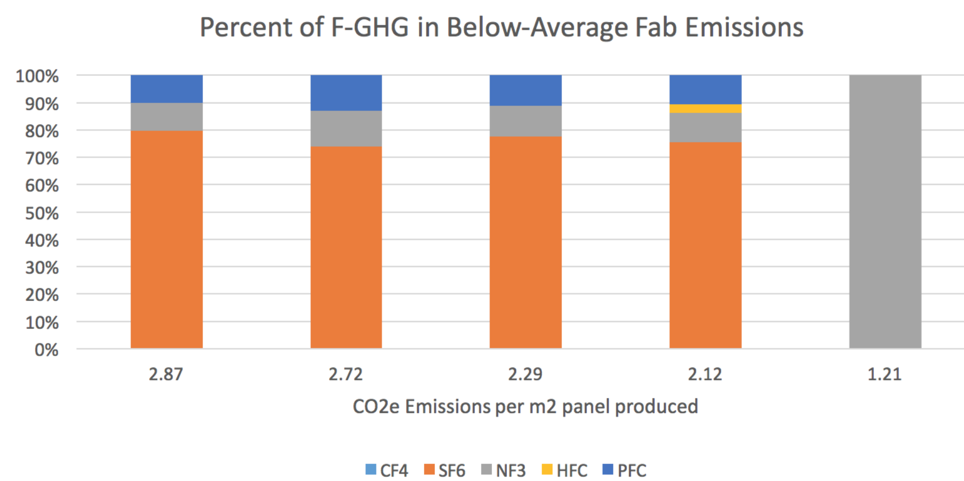
When we calculated the emissions per M^2 of panel produced in 2014, we also saw a wide disparity across different fabs. The average M^2 of panel led to emissions of 41 kilograms CO_2e. Just under a third of total fabs are above the average and approximately 70 percent are below average. The most efficient 33 percent are all hovering close to 5 kg CO_2e per M^2 produced.



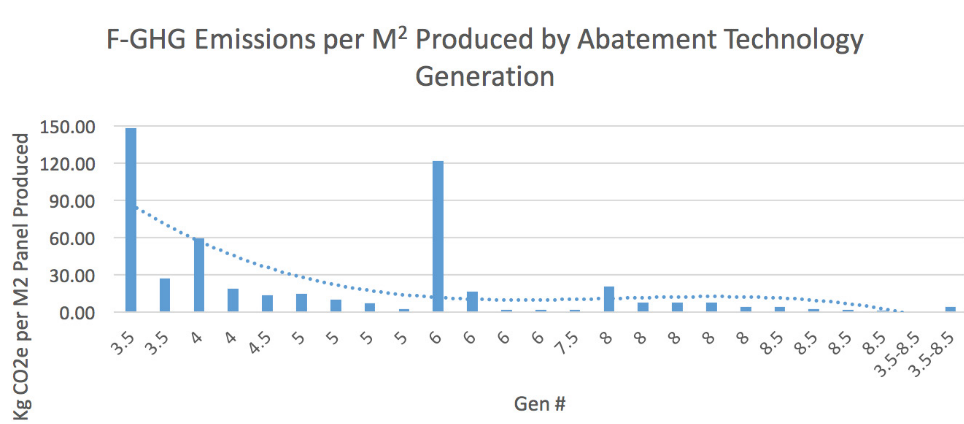
If we look at emissions by F-GHG per M^2 produced for all fabs with above-average emissions per area produced, we see that SF_6 is clearly the leader in contributing to those above-average emissions. NF_3 is also a major contributor in two of these fabs. None of the other F-GHGs contribute more than 10 percent of the total emissions.

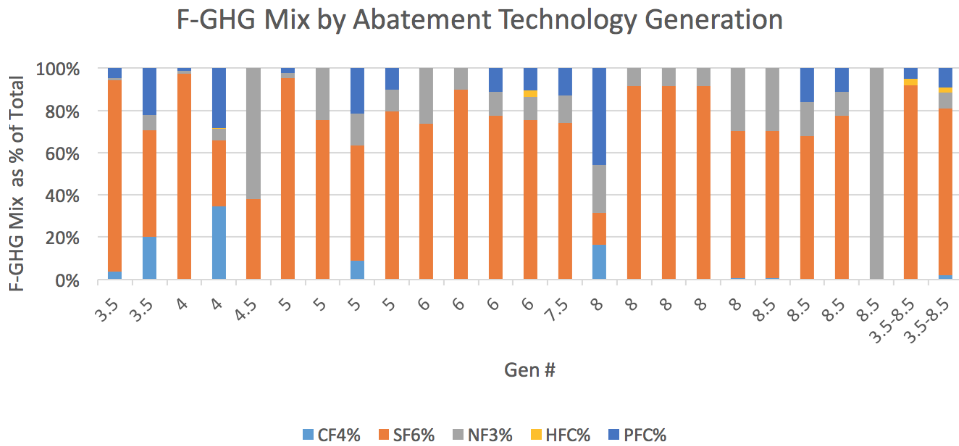


For the below-average fabs, you can see that while SF_6 remains the primary F-GHG emitted, PFCs become more significant, and NF_3 is the sole contributor for one of the fabs.

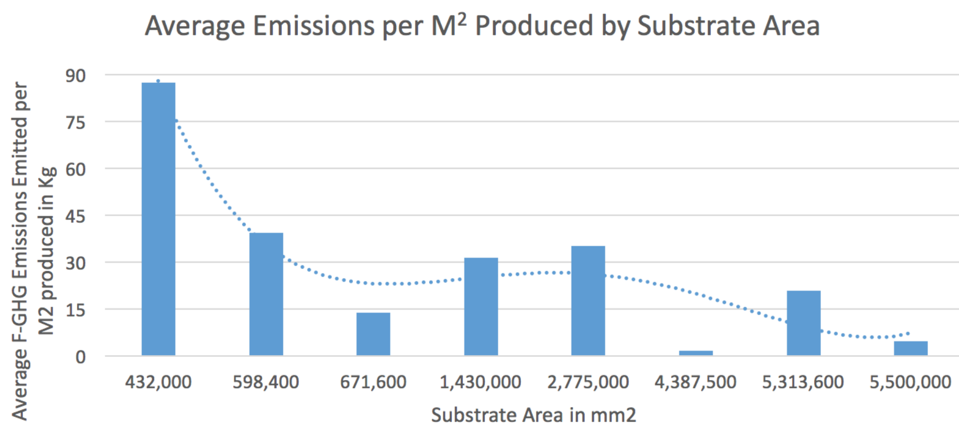


When we turn our attention to some of the details at the fabrication facility level, a number of interesting trends appear. First of all, abatement technology generation (Gen) number appears to influence the normalized emissions. However, a few outliers appear in the chart below. The cause of the outliers is difficult to identify, because there is no abatement information available and the gas mix below makes it clear that SF_6 remains the critical substance in question.

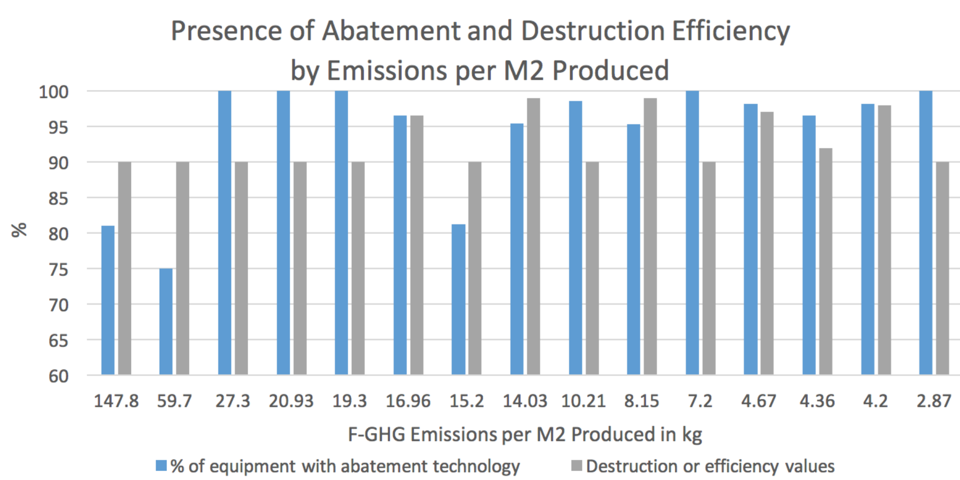




Next, we looked at average emissions per M^2 produced as compared to the reported substrate area in the fab. Substrate describes the glass input area. These companies reported substrate areas in eight distinct sizes, ranging from 432,000 square millimeters to 5,500,000 square millimeters. We averaged the normalized emissions for all the different substrate areas. A fairly clear downward trend falls along with increasing substrate area. Interestingly, we note that higher emissions intensity in the smaller substrate areas correlates well with the product analysis because larger panels, such as televisions, showed lower emissions intensity than smaller panels in vehicle and industrial displays.



As for abatement systems, it is difficult to find strong correlation between their use, efficiency, and lower emissions; partly because we only know the gas mix and not the specific gas input. Another factor is the wide array of abatement in place. Some companies reported having an abatement system for all of their tools, others reported having a single system for the entire fab, and others reporting having no abatement at all. Those that reported no abatement systems also reported using F-GHGs with lower GWP. Those companies that did indicate using abatement systems generally estimated 90 percent efficiency rates for those systems, with some estimating 99 percent. As expected, the highest emissions per M^2 produced is correlated to reported low installation percentages for abatement technology.



CONCLUSIONS

- SF_6 is the most critical of these F-GHGs in terms of emissions. Identifying appropriate processes or technologies to mitigate these SF_6 emissions would represent the most-effective way to reduce emissions in this sector.
- No trend exists in the use and efficacy of abatement technology in reducing F-GHG emissions. Even though abatement remains critical to controlling GHG emissions, and its use is widespread, the lack of correlation suggests that few best practices or substantial further emissions reductions can be gleaned.
- We do see that Gen and panel size impact emissions intensity. Perhaps there are lessons that may be applied from those fabs. For example, can certain aspects of high Gen number and panel size be applied to others?
- For the least emissions-intensive fabs, the use of PFCs and NF_3 indicate that technologies, substance alternatives, abatement technologies, or processes may be in place at those fabs to help control emissions across the sector.

We look forward to continuing this survey to have the chance to explore how these emissions may change over time.