F-GHG Emissions Reduction Efforts: 2018 Supplier Profiles

U.S. Environmental Protection Agency
Office of Air and Radiation
March 2020

The Supplier Profiles outlined in this document detail the efforts of large-area flat panel suppliers to reduce their fluorinated greenhouse gas (F-GHG) emissions in manufacturing facilities that make today's large-area panels used for products such as TVs and computer monitors. More comprehensive information on how F-GHGs are used in flat panel display (FPD) manufacturing is available on the Center for Corporate Climate Leadership's website at: https://www.epa.gov/climateleadership/center-corporate-climate-leadership-sector-spotlight-electronics.

Summary of Supplier Profiles

The table below on page six summarizes which panel suppliers publicly report their F-GHG emissions, their most recent F-GHG emissions, and, where available, their F-GHG emissions intensity based on panel production. It also includes information on suppliers' broader GHG emission reduction goals, since F-GHGs comprise a significant portion of on-site Scope 1 GHG emissions,[1] as well as the regulatory and/or voluntary efforts by which suppliers are reducing their F-GHG emissions.

Most importantly, the table highlights which suppliers have fully implemented F-GHG emissions reduction measures across their older and newer manufacturing, or fabrication, facilities, also referred to as 'fabs.' For panel suppliers that have not fully implemented F-GHG reduction measures, whereby approximately 90 percent of annual F-GHG emissions are avoided or removed, further opportunities for improvement exist.

The summary table and charts below reflect data, assembled from public sources and the suppliers themselves, on F-GHG emissions for calendar year or fiscal year 2018, depending on the supplier's reporting cycle. Public sources of information include suppliers' responses to the annual CDP Investor Questionnaire and each supplier's annual sustainability or corporate social responsibility reports.

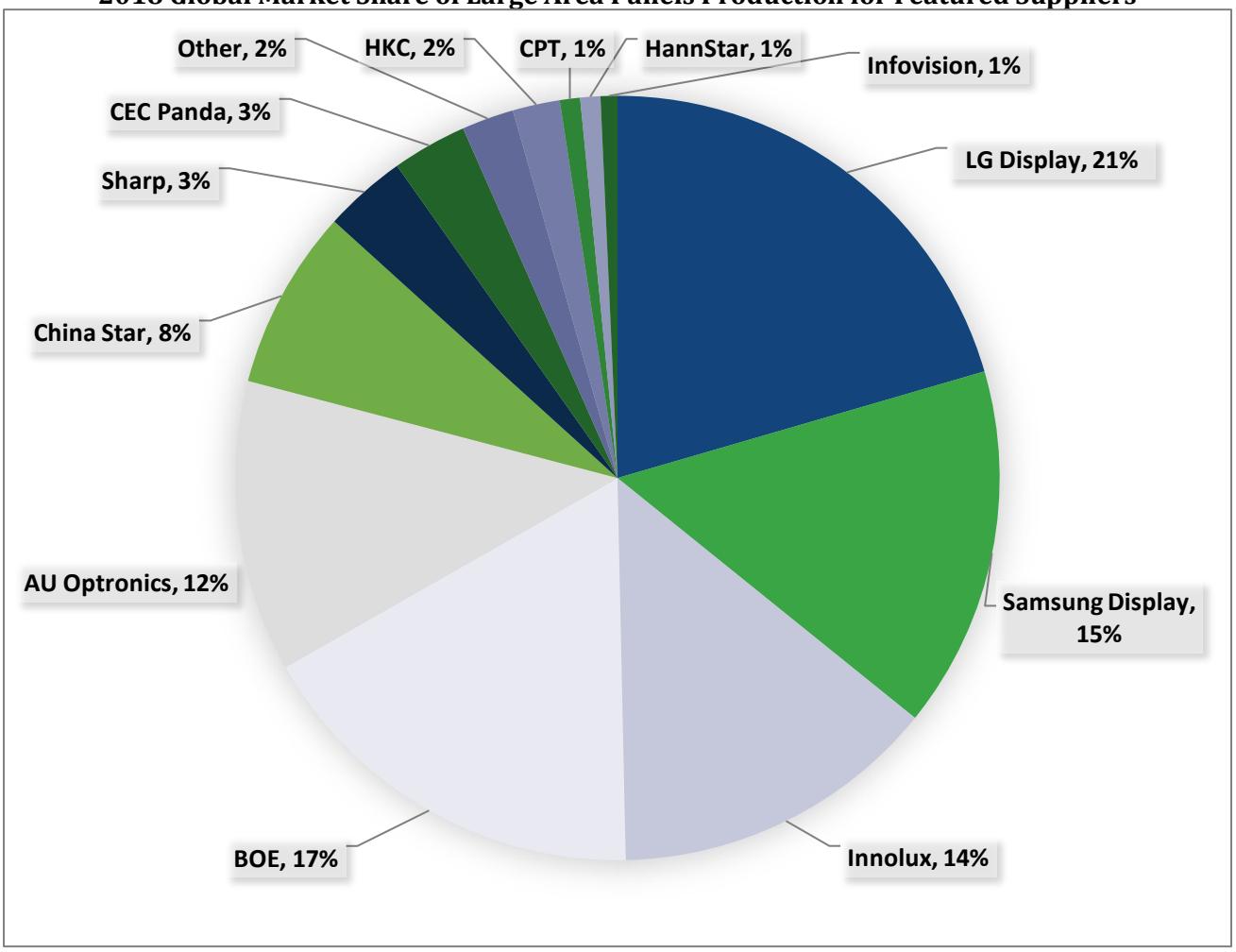
Following the summary information, individual profiles provide more information on specific methods, such as abatement, process optimization and use of alternatives that suppliers are using to reduce their F-GHG emissions.

[1] Scope 1 GHG emissions are an organization's direct emissions from sources that are owned or controlled by that organization.

Supplier Market Share

The thirteen global flat panel display suppliers named among the profiles produce 96%[2] of all large-area flat panel displays sold globally, as shown in the chart below[3]. Large area panels are defined as being 9.1 inches or larger.

2018 Global Market Share of Large Area Panels Production for Featured Suppliers



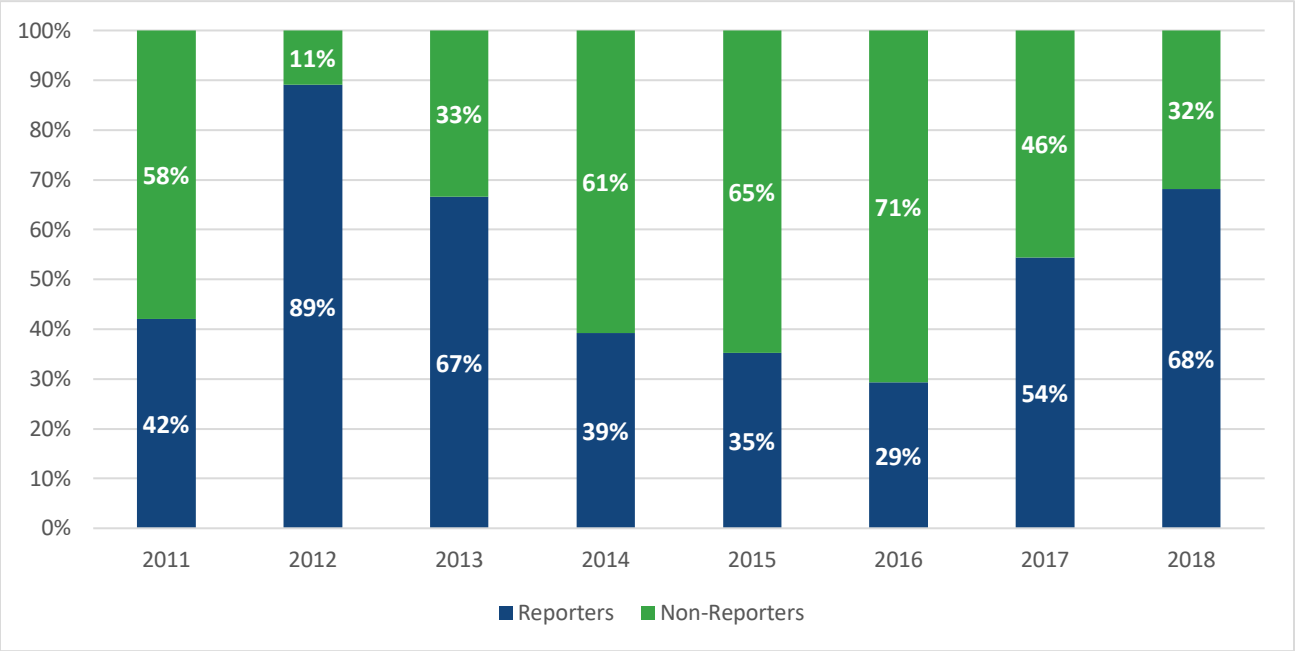
Note: Market share includes only large area displays, however, emissions reported in subsequent sections may include totals associated with all sizes of flat panel displays.

Source: IHS Technology 2018. "Large Area Display Production Strategy Tracker."

[2] Source: IHS Technology 2018. "Large Area Display Production Strategy Tracker."

[3] Total percent of market shares may exceed to be less than 100%, due to rounding.

Relative Market Share for Publicly Reported F-GHG Emissions [4,5]



Source: IHS Technology. Large Area Display Production Strategy Tracker.

Key Findings Based on 2018 Data

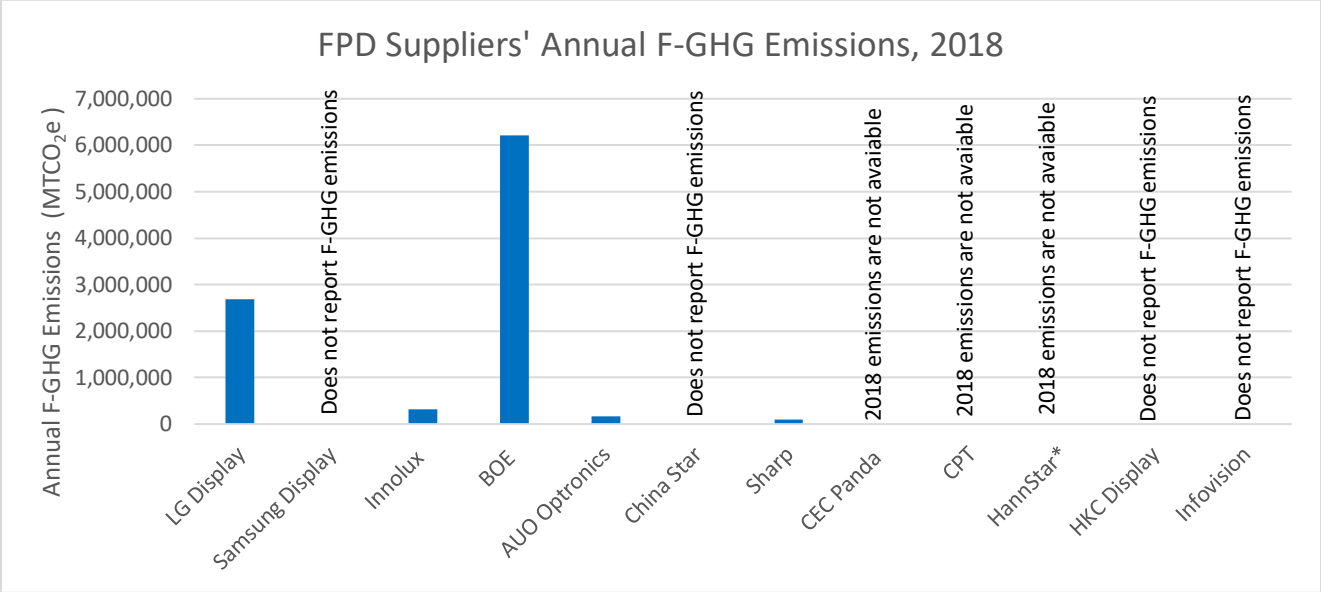
- Six global LCD suppliers, representing 68% of LCDs manufactured in 2018, reported their annual F-GHG emissions and/or reduction efforts. Suppliers AOU, Innolux, and Sharp have consistently reported on their F-GHG emissions since 2012 and LG Display has reported publicly again for the second consecutive year. As 8 years of data demonstrate (Previous Supplier Profiles), key suppliers have been maintaining and/or improving F-GHG reductions over time. Additionally, the 2018 profiles see the first public reporting of F-GHG emissions for BOE, whose market share has increased substantially over the last five years, also pointing to improved transparency in regional LCD manufacturing.
- Some suppliers who previously reported annual F-GHG emissions did not provide their F-GHG emissions for their 2018 calendar year reports. While some liquid crystal display (LCD) suppliers have reported, and continue to report, their F-GHG emissions publicly, others with large and/or increasing market share opt to report their F-GHG emissions either privately or directly to their customers. Thus, greater transparency is still needed on all LCD panel suppliers' F-GHG emissions to better understand overall trends in F-GHG emissions. An improved understanding is needed on the extent to which F-GHG emission reductions result from both the use of F-GHG reduction technologies and the use of lower GWP F-GHGs in key processes. This will better equip brands to understand all methods their

[4]In 2012, Samsung (18% market share in 2012) and LGD (26% market share in 2012) reported their F-GHG emissions which contributes to the high market share of reporters. In 2013, LGD continued to reported emissions in. In 2014-2016 LGD did not report their F-GHG emissions which caused the decline in publicly reported F-GHG emissions. In 2017, LGD resumed reporting their F-GHG emissions, resulting in an increase in publicly reported F-GHG emissions.

[5] Panasonic exited the Flat Panel Display market in 2015. Panasonic reported emissions consistently while their facilities were producing flat panel displays.

suppliers implement to reduce F-GHG emissions. For example, LG has replaced use of SF_6 with NF_3 in the etch process, which has resulted in significant emissions reductions.

- An optimal F-GHG emission intensity, based on full abatement and/or the fullest use of lower GWP gases, could serve as an indicator on whether F-GHG emission reduction efforts have been implemented to the fullest extent possible. In 2018, AU Optronics' F-GHG emission intensity was 0.0027 MtCO2e/m2, a 4% increase since 2017. Since 2005, their F-GHG intensity has been reduced over 95% from 0.0057 MtCO2e/m2 in 2005 to 0.0027 MtCO2e/m^2. AUO's F-GHG emission intensity was the lowest publicly reported intensity metric, however only three suppliers total (AUO, Innolux, and Hannstar) reported F-GHG emission intensity for 2018.



Note: CEC Panda reported emissions in 2016 but not in 2017 or 2018. CPT did not respond to the 2019 CDP Climate Change Questionnaire; thus its 2018 emissions are not publicly available.
*HannStar provides some details on its 2018 F-GHG emissions reduction efforts but does not provide its actual 2018 F-GHG emissions data.

Source: Data from publicly available sources as detailed in the individual supplier profiles**.**

IEEE 1680.1 Standard

- In March 2018, the ***IEEE 1680.1-2018 Standard for Environmental and Social Responsibility Assessment of Computers and Displays*** was published, replacing a previous version.
- This standard includes new criteria that incentivize improvements across many different environmental impacts. One of the new optional criterion addresses F-GHG emissions reductions by flat panel display suppliers. For a brand manufacturer (Original Equipment Manufacturer (OEM)) to declare that a product containing flat panel displays meets the F-GHG criteria and conforms to the standard, at least 75% of its flat panel display suppliers, by amount spent during the annual fiscal or calendar year, must demonstrate that they are reducing annual F-GHG emissions by 90 percent.

- The revised IEEE 1680.1 standard aims to foster greater sustainability in the Information Technology (IT) supply chain since the criteria of the standard underpin the Electronic Product Environmental Assessment Tool (EPEAT), a sustainability rating tool for certain electronics. An IT product receives an EPEAT Bronze, Silver, or Gold rating. Bronze-rated products meet minimum required criteria only, whereas Silver and Gold-rated products also meet additional amounts of optional criteria.
- Computer and Display products that are "EPEAT registered" will be required to meet the IEEE 1680.1 standard. A registry of conformant products is publicly available at www.epeat.net as of November 2018.
- Many institutional purchasers around the globe purchase EPEAT- registered products. By searching the registry, purchasers can determine if EPEAT-registered products containing flat panel displays, namely monitors and laptops, meet the optional F-GHG emissions reduction criterion.

    By March 2020, 6048 EPEAT-registered products from six companies (ASUSTek, Acer, Google, HP, Lenovo, Positivo Technologia S.A., and Teknoservice S.L.) had met the criteria for F-GHG emissions reductions from flat panel display manufacturing

F-GHG Emissions in Context of Scope 1 and 2 Emissions Reductions Efforts

As electronics brand owners increasingly request that suppliers report and reduce their Scope 1 and 2 emissions, several LCD suppliers have also begun to implement energy efficiency measures and purchase renewable energy to mitigate their overall GHG emissions. Some suppliers provide detailed insights on energy savings measures in their CDP and/or CSR reports. In some instances, where noted in the profiles, it is unclear if efficiency measures apply to equipment that utilizes F-GHG more efficiency, or if such measures apply to non-F-GHG equipment. EPA is interested in better understanding the tradeoffs between reducing on-site combustion and electricity use and installing F-GHG abatement measures that utilize on-site combustion or electricity use. Brand owners are encouraged to engage suppliers on their holistic approaches to reducing both Scope 1 and 2 emissions. As such, where data is available, EPA has included information on other energy saving measures under the "Emission Reduction Goals and Progress" sections.

Summary of F-GHG reporting reduction activities by LCD supplier																				
Company	**Market Share of FPD Production**	**Publicly Reported 2018 F-GHGs**	**2018 F-GHG Emissions** ($MtCO_2e$)	**% Reduction from 2016**	**2018 F-GHG Intensity** ($MtCO_2e/m^2$ of panel produced)	**GHG Reduction Goals**[6]	**National Regulations on F-GHGs/Carbon Trading**	**Participation in Voluntary National/International (i.e., WDICC) F-GHG Efforts?**	**F-GHGs Targeted by Emission Reduction Efforts**				**Processes Targeted by Emission Reduction Efforts**			**Reduction Approach(es) Used**				**Full F-GHG Emission Reduction Measures Implemented at Each Fab (resulting in overall ~90% F-GHG emission reductions across all fabs)**	
									SF_6	PFCs	HFCs	NF_3	Etch	Clean	Heat Transfer	Abatement	Process Improvements	CVD Remote Plasma	Other	Newer Fabs (built after 2003)	Older Fabs
LG Display	21%	✓	2,681,472	+6%	Not Available	16.8% by 2022 (2014 baseline)	✓	✓	✓	✓	✓	✓	✓	✓	F-GHGs not used	✓	✓	✓			
BOE	17%	✓	6,213,824	N/A	Not Available	No											✓		✓		
Samsung	15%	-	2018 F-GHG emissions data is not publicly available.	N/A	Not Available	No	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓				
Innolux	14%	✓	317,065	-18%	0.0044	Lower emissions intensity 30% by 2025 (2016 baseline)	✓	✓	✓	✓	✓	✓	✓	✓	not inventoried	✓	✓			✓	✓
AU Optronics	12%	✓	170,282	-5%	0.0027	24.7% by 2020 (2015 baseline)	✓	✓	✓	CF_4	✓	✓	✓	✓	deemed too minor	✓	✓			✓	✓
China Star	8%	*2018 F-GHG emissions data is not publicly available.*																			

[6] For more information on GHG emission reduction goals, including the base year and scope of included emissions, see the individual Supplier Profiles.

Sharp	3%	✓	92,833	-2%	Not Available	No		✓	✓	CF_4	CHF_3	✓	✓	✓	no info available	✓	✓		✓	✓	✓
CEC Panda	3%	*2018 F-GHG emissions data is not publicly available.*																			
HKC	2%	*2018 F-GHG emissions data is not publicly available.*																			
CPT	1%	-	2018 F-GHG emissions data is not publicly available.	N/A	Not Available	No		✓	✓	✓	✓	✓	✓	✓	no info available	✓	✓			✓	
HannStar	1%	✓	Some data on 2018 F-GHG emissions reduction efforts publicly available. Actual 2018 F-GHG emissions not publicly available.	N/A	0.073	No	✓	✓	✓			✓	✓	✓	F-GHGs not used	✓	✓			✓	
Infovision	1%	*2018 F-GHG emissions data is not publicly available.*																			

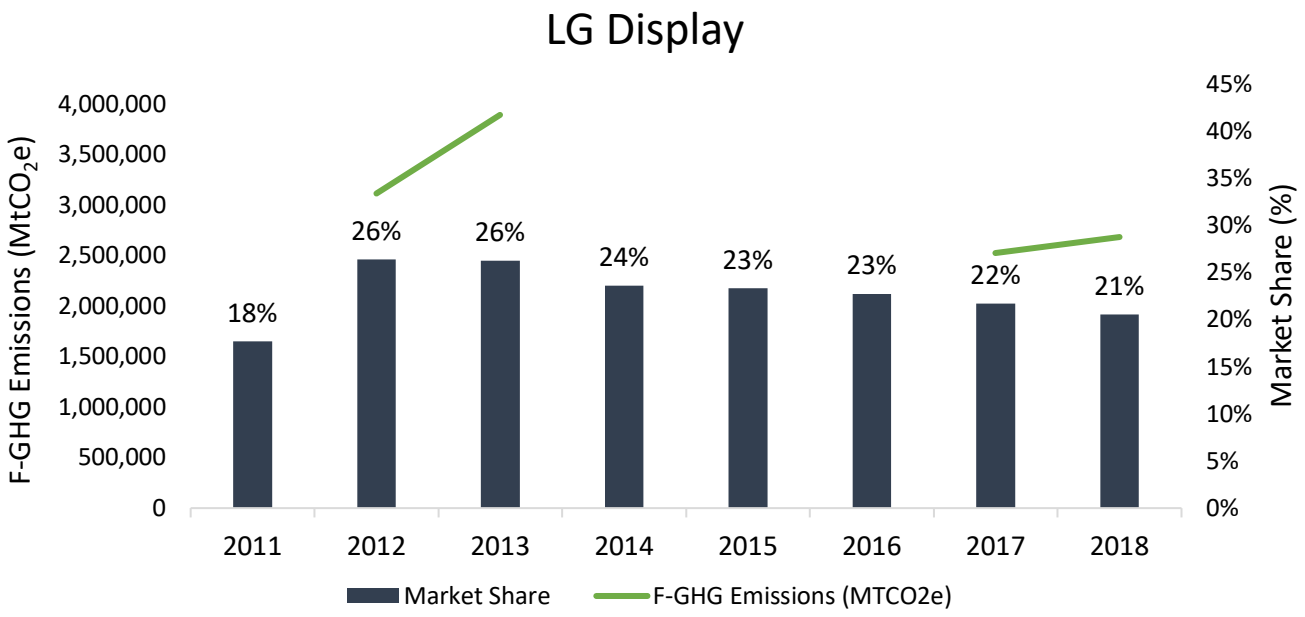
Flat Panel Display Supplier 2018 Profiles

Flat panel display suppliers are presented in descending order of market share.

LG Display 2018 Data

21% Market Share

F-GHG Emissions Over Time



The chart above shows the following separate but related metrics:

- ***Market share** over time shows the size of the supplier relative to all suppliers in the industry based on area of panels produced.*
- ***Total emissions** over time show total F-GHGs emitted by the supplier each year. Supplier emissions can change due to the implementation of emissions reduction efforts, an increase or decrease in panel production, and/or LCD technology advancements.*
- ***Emission intensity**, noted where data is available, is a measure of the amount of F-GHG emissions per unit of production. Trends in emission intensity show whether the supplier's rate of emissions is increasing or decreasing over time and can indicate whether the supplier is implementing emission reduction efforts. LG Display does not publicly report F-GHG emission intensity.*

F-GHG emissions are publicly reported by suppliers through the CDP (formerly "Carbon Disclosure Project") and/or corporate sustainability reports. In this graph, market share is calculated based on production data from IHS Technology.

F-GHG Emission Reduction Activities

Overview

- In 2018, LG Display emitted approximately 2,681,472$MtCO_2e$ of F-GHG's as follows:
  - PFCs: 191,622 MtCO2e
  - HFCs: 441 MtCO2e

- SF6: 2,489,245 $MtCO_2e$

Gases Targeted

- SF_6
- PFCs
- NF_3

Processes Targeted

- Etching
- Cleaning

Approaches Used

Abatement

- **Abatement Systems:** LG Display has installed F-GHG abatement systems on all lines of cleaning tools and on two lines of etching tools. Electrically heated point-of-use systems are installed for NF_3 in cleaning tools and combustion-type centralized systems are installed for SF_6 and PFCs in etch tools.

Process Improvements

- LG Display has applied end-point detection and revised processes to optimize the use of F-GHGs.

Alternative Chemicals

- **SF_6 Replacement:** In 2014, LG Display developed a gas application technology as an alternative to using SF_6 and has started implementing the use of the alternative. In 2015, since joining the Korean emission trading scheme, LG Display replaced SF_6 as a process gas used in dry etching with NF_3, which has a lower GWP. At its Paju, Korea plant, the use of SF_6 in 2017 decreased by 44% from 2015 levels. The total amount of SF_6 use in the overall plants in 2018 decreased by 38.2% compared to 2015, and this is equivalent decrease to 1,279,626 tons of CO_2.
- **Remote Plasma Source Chamber Clean:** LG Display has applied NF_3 remote plasma source chamber clean (RPSC) to all manufacturing lines. RPSC's utilization rate is 97% compared to 70% for an ordinary chamber.
- **NF_3 Replacement:** LG Display has replaced NF_3 with F_2 in chamber cleaning on one of its manufacturing lines. LG Display continues to research alternative lower GWP etching gases than SF_6 for the dry etching process.
- LGD invested 3.8 billion won (₩) (in 2016, 1 ₩ = 0.00088 USD[7]) for the development of clean production technology to replace SF_6 to respond to the greenhouse gas emissions trading scheme. Currently, SF_6 gas replacement technology is applied in major plant facilities to reduce greenhouse gas emissions. In 2017, about 1.6 billion ₩ was invested in scrubbers, which are process gas cracking facilities to further reduce greenhouse gas emissions.

[7] Source: xe.com. Accessed on 18th April 2019

Emissions Measurement Approaches and Verification

- LG Display uses national GHG emission estimation guidelines issued by the South Korean Ministry of Environment and estimates NF_3 emissions by using the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories Tier 2b guidelines.
- LG Display uses the CDM methodology AM0065 as the verification criteria for their SF_6 replacement processes since the methodology. This verification occurs once per year, and applies to domestic facilities which have replaces SF_6 with NF_3.
- LG Display's GHG emissions are verified by a third party in accordance with South Korean government regulations. NF_3 emissions estimated by the 2006 IPCC Tier 2b Guidelines for National Greenhouse Gas Inventories for electronics industry emissions are not assured by a third party but cross-checked by the World Display Device Industry Cooperation Committee (WDICC) members.

Emission Reduction Goals and Progress

- LG Display set a target to reduce Scope 1 and Scope 2 GHG emissions 16.8% by 2022 and 65.1% by 2045, all relative to 2014 levels. Scope 1 emissions include F-GHGs.
- LG Display reduced GHG emissions by 17.2% in 2018 compared to 2017 through process gas replacement and energy saving campaigns.
- At its Paju plant, LG Display reduced the use of SF_6 in 2017 by 44% compared to 2016 through the alternative use of NF_3.
- LG Display's F-GHG emissions reduction efforts are part of its broader goals to reduce corporate-wide GHG emissions.
- LG Display is subject to emissions caps under the Korean Emissions Trading Scheme (K-ETS) and has been participating in GHG emissions trading since January 2015. The K-ETS is the first nationwide Cap-and-Trade program in operation in East Asia.
- In 2015, LG Display implemented its Carbon Footprint Calculator to respond to government GHG regulations and respond to customer preference for environmentally friendly products.
  LG Display is a member of the Korea Display Industry Association (KDIA), where it participates in an environmental working group that promotes information exchange on GHG emissions reduction technologies and initiatives. KDIA represents Korea's flat panel display suppliers in the World Display device Industry Cooperation Committee (WDICC).

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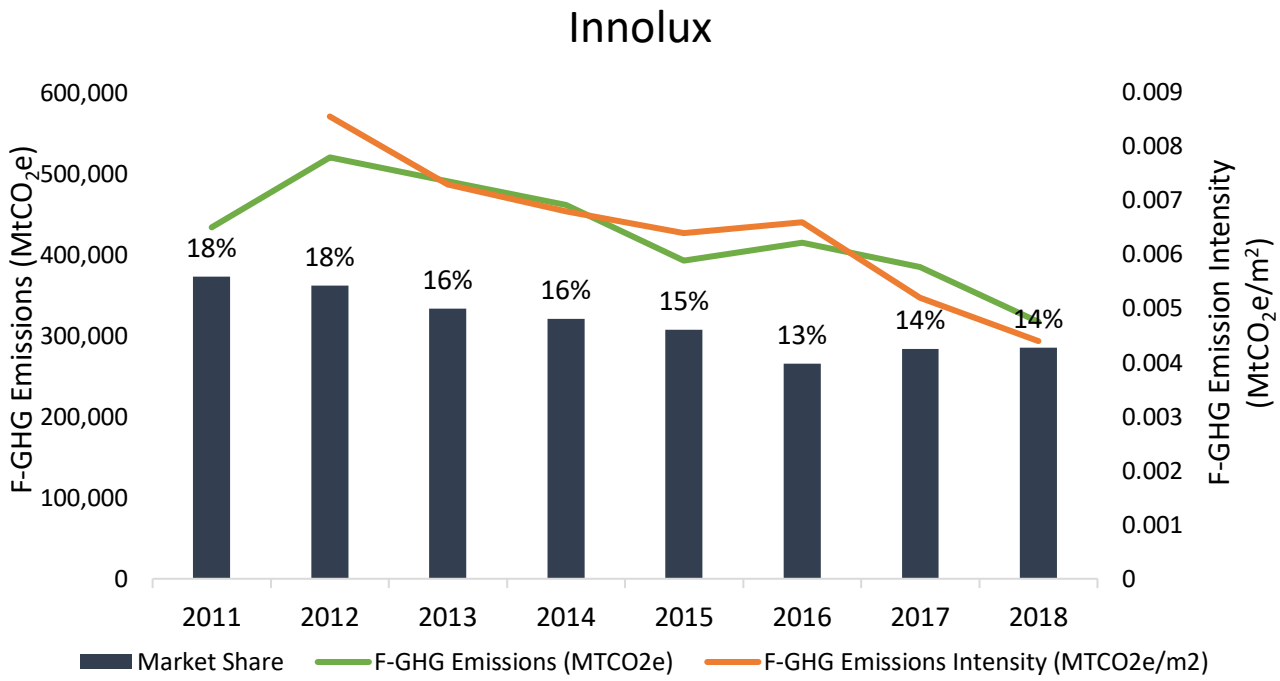
Innolux Corporation 2018 Data

14% Market Share

F-GHG Emissions Over Time



The chart above shows the following separate but related metrics:

- ***Market share** over time shows the size of the supplier relative to all suppliers in the industry based on area of panels produced.*
- ***Total emissions** over time show total F-GHGs emitted by the supplier each year. Supplier emissions can change due to the implementation of emissions reduction efforts, an increase or decrease in panel production, and/or LCD technology advancements.*
- ***Emission intensity**, noted where data is available, is a measure of the amount of F-GHG emissions per unit of production. Trends in emission intensity show whether the supplier's rate of emissions is increasing or decreasing over time and can indicate whether the supplier is implementing emission reduction efforts.*

F-GHG emissions are publicly reported by suppliers through the CDP (formerly "Carbon Disclosure Project") and/or corporate sustainability reports. In this graph, market share is calculated based on production data from IHS Technology.

Note: While market share data include only the production of large area panels, emissions and intensity totals reported by Innolux are from the production of all sizes of flat panel displays.

F-GHG Emission Reduction Activities

Overview

- In 2018, Innolux emitted approximately 317,065 metric tons of CO_2 equivalent ($MtCO_2e$) of F-GHGs, as follows:
    - HFCs: 9,645$MtCO_2e$
    - PFCs (includes NF_3): 58,319 $MtCO_2e$ (54,651$MtCO_2e$ (NF_3) + 3,668$MtCO_2e$ (PFCs))
    - SF_6: 249,102$MtCO_2e$
- In 2018, Innolux reported that removal (F-GHG abatement) equipment reduced total annual F-GHG emissions by 2,821,486 $MtCO_2e$, compared to 3,029,691 $MtCO_2e$ reduced in 2017, and 2,865,222 $MtCO_2e$ reduced in 2016 (a 6.9% decrease compared to 2017).
- In 2018, F-GHGs represented 8.8% of Innolux's overall GHG emissions compared to 10.6% of total emissions in 2017[8].

Emissions Intensity:

- F-GHG intensity per substrate at the TFT-LCD stage of Taiwan has been reduced over 30% from 0.0094 $MtCO_2e/m^2$ in 2010 to 0.0064 $MtCO_2e/m^2$ in 2016.
- In 2017, the F-GHG emission intensity per input substrate at the TFT-LCD stage of Taiwan sites was 0.0052 $MtCO_2e/m^2$.
- In 2018, the F-GHG emission intensity per input substrate at the TFT-LCD stage of Taiwan sites was 0.0044 $MtCO_2e$/m2, which was reduced 15.4% compared with 2017.

Gases Targeted

- SF_6
- PFCs
- HFCs
- NF_3

Processes Targeted

- Cleaning
- Etching
- *Innolux uses a small amount of fluorinated heat transfer fluids but has not inventoried them. In anticipation of the upcoming updates to the IPCC Guidelines, Innolux is documenting the amount of heat transfer fluids purchased in 2015 to 2018.*

Approaches Used

Abatement

- Innolux has installed the tail gas treatment unit to conduct thermal destruction for reduction of F-GHGs emission. Local combustion scrubbers were installed in Fab3 in Tainan to remove SF_6 emitted during the etching process by combustion.

[8]In 2018, Innolux's total Scope 1 emissions accounted for 10.3% of their total emissions, meaning F-GHG emissions make up the majority of Innolux's Scope 1 emissions.

- Innolux has installed local combustion scrubbers. In 2018, Innolux reported reducing 2,821,486MtCO_2e of F-GHGs[9].

Process Improvements

- Innolux is optimizing the use of F-GHGs in the process chambers. Additional details not available.

Alternative Chemicals

- **SF_6 Replacement:** Innolux has planned to replace SF_6 with NF_3 in the etching process in some of its factories.
- Innolux is using lower GWP gases, where possible.

Emissions Measurement Approaches and Verification

- Innolux estimates F-GHG emissions based on the Tier 2b method for electronics industry emissions provided in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.
- Innolux received third party verification for its GHG inventory every year until 2017, which was verified in accordance with the ISO 14064-3 standard.
- In 2018, Innolux verified their emissions in accordance with the ISO 14064-3 standard.
- Innolux has collected data for 13 years and passed the third-party verification according to ISO 14064-1.

Emission Reduction Goals and Progress

- In 2013, Innolux released its Product Carbon Footprint (PCF) system to help streamline calculations of emissions on a per product basis.
- In 2018, Innolux audited the carbon emissions of the top 89% of suppliers who inventoried their GHG emissions. Innolux exceeded its 2018 target of reducing carbon emission of suppliers by 135,000MtCO_2e and achieved a reduction of 136,513MtCO_2e.
- Innolux plans to continue monitoring carbon emissions to establish a comprehensive database.
- Innolux applied for early carbon credits for its carbon reduction efforts between 2005 and 2011, receiving 16 million tons in credits in 2015 for Taiwan's cap and trade program.
- In 2017, Innolux applied to the Taiwan EPA for the carbon offset program. The application for reduction credits was agreed to after initial review, expecting a reduction of emissions by 35,000 CO_2e per year. In 2018, Innolux acquired approval for this greenhouse gas exchange program. In 2018, Innolux donated 2,048 energy-saving white LED tubes to replace the fluorescent tubes at Private Changtai and Nursing Institute of Taiwan. It is estimated that the new lights will reduce carbon emissions by 56,093 kg CO2e.

[9] F-GHG emission reductions reported by Innolux in February 2020. Innolux's CDP report includes 0.769 MMTCE, which equals 2,819,667 Mt CO2e, thus very similar F-GHGH emission reductions.

- Innolux set a long-term goal for all manufacturing sites in Taiwan to reduce F-GHG emission intensity per square meter of glass produced at the TFT-LCD by 30% by 2025 compared with 2016.

Participation in Broader F-GHG Reduction Efforts

- Innolux is a member of Taiwan's TFT-LCD Association (TTLA). The TTLA participates on behalf of Taiwan's LCD suppliers in the World Display device Industry Cooperation (WDICC), whose members have agreed to 30% F-GHG emission reductions by 2020 relative to 2010 levels.

Sources

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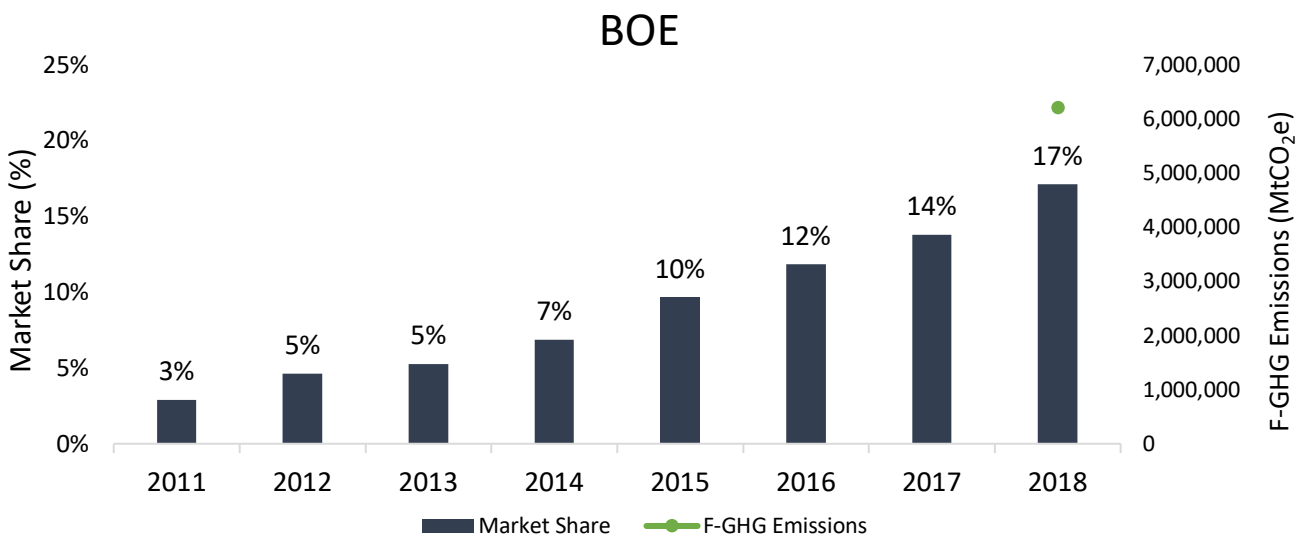
BOE FY 2018 Data

17% Market Share

F-GHG Emissions Over Time



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- ***Emission intensity**, noted where data is available, is a measure of the amount of F-GHG emissions per unit of production. Trends in emission intensity show whether the supplier's rate of emissions is increasing or decreasing over time and can indicate whether the supplier is implementing emission reduction efforts.*

F-GHG emissions are publicly reported by suppliers through the CDP (formerly "Carbon Disclosure Project") and/or corporate sustainability reports. In this graph, market share is calculated based on production data from IHS Technology.

F-GHG Emission Reduction Activities

Overview

- In 2018, BOE emitted approximately 6,213,824 metric tons of CO_2 equivalent ($MtCO_2e$) of F-GHGs, as follows:
    - HFCs: 65,940 $MtCO_2e$
    - SF_6: 6,147,884 $MtCO_2e$

Emissions Intensity:

- BOE's 2018 emissions intensity data is not publicly available.

Processes Targeted

- Etching
- Cleaning
- Heating/Cooling

Approaches Used

Information on Abatement, F-GHG Process Improvements, Alternative Chemicals, or other F-GHG Reduction Approaches not publicly available.

Emissions Measurement Approaches and Verification

- BOE's 2018 Scope 1 emissions sources include emissions statistics for natural gas, diesel, gasoline, carbon dioxide fire extinguishers, personnel activities, refrigerants, and the use of SF_6 and CO_2 in the production process.
- BOE's 2018 Scope 2 emissions are calculated from the CO_2 emissions generated by the consumption of purchased electricity, using the China Development and Reform Commission's grid emission factor.
- A third party provides reasonable assurance of BOE's Scope 1 and 2 emissions data according to the ISO14064-3 guidance.

Emission Reduction Goals and Progress

- BOE set a goal to reduce Scope 1 and 2 emissions intensity by 20% from 2018 to 2028.
- BOE set an energy usage goal to reduce the ratio of energy consumption (kwh) to dollars of output value by ten thousand dollars of output value in 2028 compared to 2017 levels.
- BOE's green development targets include aiming to become a leading exemplar of green development in the industry by 2022 by demonstrating the lowest levels of energy/water consumption and direct/indirect greenhouse gas emissions per unit of added value or per unit of product in the industry.
- In total BOE has completed implementation of 38 emissions reductions initiatives, with four additional projects in early stages. The 38 completed initiatives reduce an estimated 152,162 $MtCO_2e$ annually.

- Heat recovery and cooling technology: BOE is using air compressor waste heat recovery to reduce power consumption and improve heat recovery, saving an estimated 9329 metric tons of CO_2 annually. BOE also introduced a condenser improvement project, air temperature optimization project, pre-cooling equipment, free cooling project, and low temperature FGI project.
- Process optimization: BOE introduced an air conditioning energy management system and changed its cooling tower fan to an inverter fan to conserve energy. BOE also improved its air compressor group control system, positively reduced its clean room pressure, adjusted FFU speed, reduced APP rated voltage, and began transformer optimization management.
- Equipment modification: BOE increased process efficiency by improving their vacuum inverter and modifying their AN04 equipment, OVEN equipment, CIPI equipment, and PA equipment. Additionally, BOE made improvements to their gluing machine, zero gas consumption desiccants, blower system, module workshop washing machine dryer and pure water system fans.
- Chemical Recycling: At BOE's CF factory, the organic diluent vapor in the exhaust is condensed and recycled for use in machine cleaning. Additionally, BOE's scrapped VOCs are returned to the manufacturing factory for recycling.
- In 2018, BOE introduced 3 new projects to address other types of emissions, which resulted in a reduction of 990 tons CO_2, 298.93 kg CL_2, 2.96 tons nitrogen, 29.64 tons ammonia nitrogen, and 6.34 tons fluorine.

Sources

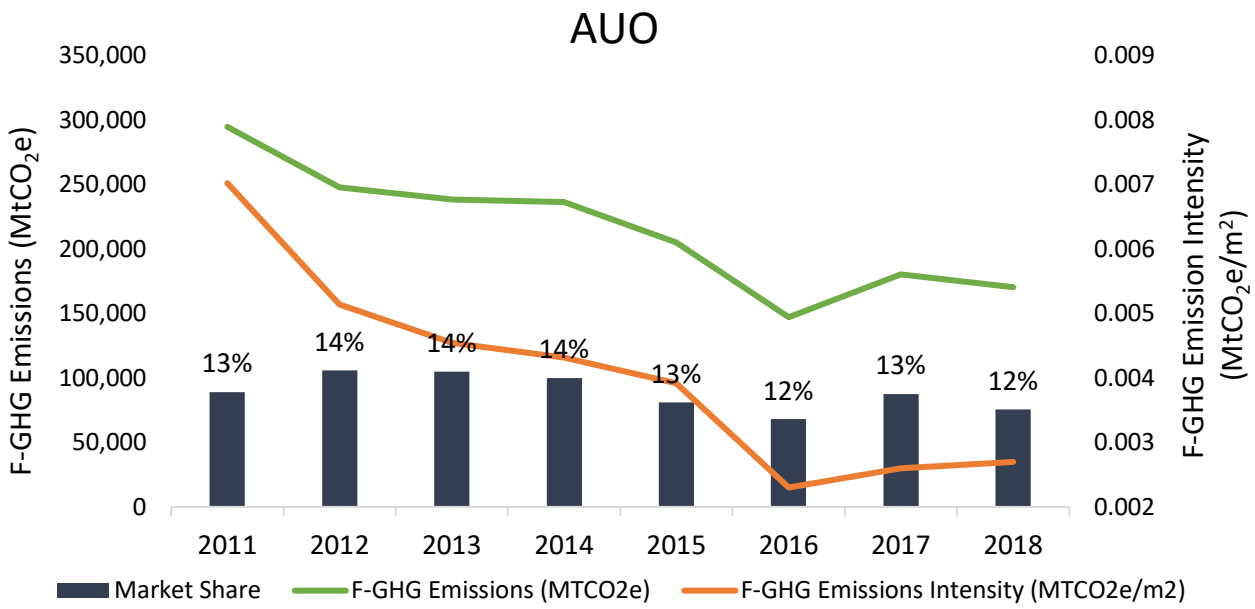
BOE 2018 Corporate Social Responsibility Report. Available at *https://www.waterdrop.cc/sd/?id=L2613FLq*

BOE's responses to the 2019 Carbon Disclosure Project Investor Questionnaire.

AUO (AU Optronics) FY 2018 Data

12% Market Share

F-GHG Emissions Over Time



The chart above shows the following separate but related metrics:

- ***Market share*** *over time shows the size of the supplier relative to all suppliers in the industry based on area of panels produced.*
- ***Total emissions*** *over time show total F-GHGs emitted by the supplier each year. Supplier emissions can change due to the implementation of emissions reduction efforts, an increase or decrease in panel production, and/or LCD technology advancements.*
- ***Emission intensity****, noted where data is available, is a measure of the amount of F-GHG emissions per unit of production. Trends in emission intensity show whether the supplier's rate of emissions is increasing or decreasing over time and can indicate whether the supplier is implementing emission reduction efforts.*

F-GHG emissions are publicly reported by suppliers through the CDP (formerly "Carbon Disclosure Project") and/or corporate sustainability reports. In this graph, market share is calculated based on production data from IHS Technology.

Note: While market share data include only the production of large area panels, emissions and intensity totals reported by AUO are from the production of all sizes of flat panel displays.

F-GHG Emission Reduction Activities

Overview

- In 2018, AUO emitted approximately 170,282metric tons of CO_2 equivalent ($MtCO_2e$) of F-GHGs, as follows:
    - HFCs: 3,801 $MtCO_2e$
    - PFCs (includes NF_3): 27,232 $MtCO_2e$ (24,893 $MtCO_2e$ (NF_3) + 2,339 $MtCO_2e$ (PFCs))
    - SF_6: 139,249$MtCO_2e$
- From 2003 to 2018, AUO reduced total F-GHG emissions by 16.4 million metric tons CO_2e.
- Together, F-GHGs used during the production process and fuel emissions of utility systems comprise most of AUO's Scope 1 emissions, representing 8.87% of AUO's total GHG emissions.

Emissions Intensity:

- In 2018, AUO's F-GHG emission intensity was 0.0027 $MtCO_2e/m^2$, a 4% increase since 2017. Since 2005 F-GHG intensity has been reduced over 95% from 0.057 $MtCO_2e/m^2$ in 2005 to 0.0027 $MtCO_2e/m^2$.
- From 2010 to 2018, AUO reduced its overall GHG emissions intensity, which includes both Scope 1 and Scope 2 GHG emissions, by 11%, from 58.5 kg CO_2e/m^2 (0.059 $MtCO_2e/m^2$) of panel produced to 51.9 kg CO_2e/m^2 (0.052 $MtCO_2e/m^2$). Since 2005, AUO has reduced the Scope 1 and Scope 2 GHG emissions per unit area of production by 69%.
- AUO has pledged to continue its efforts to achieve an additional 5% reduction in emissions intensity by 2020 to attain their 25% GHG emission reduction goal.

Gases Targeted

- SF_6
- PFCs (specifically CF_4)
- HFCs
- NF_3

Processes Targeted

- Etching
- Cleaning
- Cooling: *Per the "Guidance for Greenhouse Gas Accounting and Reporting for GHG inventory" published by the Taiwanese EPA, emissions from fluorinated heat transfer fluids are too minor in AUO's process to account for.*

Approaches Used

Abatement

- **Localized Abatement Systems:** As of 2015, AUO has installed localized, point-of-use abatement systems in all fabrication facilities (fabs).
- **Abatement for Cleaning:** AUO uses combustion abatement systems for cleaning processes in all fabs.

- **Abatement for Etching:** AUO uses combustion abatement systems or membrane separation technology for dry etching processes on all new production lines (built after 2003).

Process Improvements

- **Reduced SF_6 Consumption:** AUO's process experts worked with its SF_6 supplier to implement ways to reduce the quantity of SF_6 used in etching across all fabs. At one of its fabs, at full production capacity, adjusting relevant SF_6 process parameters can result in reducing the equivalent of 32,000 metric tons of CO_2 annually, which is equal to 18% of AUO's reported SF_6 emissions in 2015.
- **Reduced Gas Waste and Improved Utilization Efficiencies:** By installing flow meters and mass flow controllers at the front of tool chambers, on-site engineers have been able to reduce unnecessary gas waste and improve gas utilization efficiencies.
- Alternative Chemicals
- **NF_3 Substitution:** AUO uses NF_3 instead of SF_6 in cleaning, since NF_3 has a lower global warming potential (GWP) and it is used more efficiently.

Emissions Measurement Approaches and Verification

- AUO estimates F-GHG emissions based on the Tier 2b method for electronics industry emissions provided in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, including use of default destruction or removal efficiency (DRE) values for abatement.
- A third party verifies AUO's raw data according to the ISO 14064-1 guidance (verification document included below).
- AUO uses external Energy Service Companies (ESCOs) to apply the IPMVP along with third-party verification for a 3-year period to improve the materiality of the internal energy-saving proposals.

Emission Reduction Goals and Progress

- AUO set a goal to reduce Scope 1 and 2 GHG emission intensity in all fabs globally by 25% from 2010 to 2015. AUO was able to achieve 20% of this goal. F-GHGs are included as part of Scope 1 emissions.
- AUO set a subsequent goal for all manufacturing sites in Taiwan to reduce Scope 1 and 2 GHG emission intensity per square meter of glass produced by 5% by 2020 compared to 2015.
- AUO's subsequent goal has been to reduce its GHG emissions by 24.7% by 2020, with a 2015 base year, for most of its Scope 1, 2 and some Scope 3 emissions (using the location-based accounting method for Scope 2). AUO's newest goal is a 16.5% GHG emission reduction by 2025, with a 2017 base year, for its Scope 1 and 2 emissions (using the location-based accounting method for Scope 2).
- AUO has a "Green Solutions" initiative that addresses emissions reductions through operations, supply chain improvements, and product design.
- AUO announced its "Carbon 2020" strategy in 2015, which aims to reduce carbon emissions by 1 million tons by 2020 and implement strategies in all areas from the optimization of product design, material usage, manufacturing processes and logistic options to the provision of energy-efficient solutions to customers. AUO supports the Science Based Targets (SBT) for a 2°C scenario and reports that it "has taken action in this direction."
- Following AUO EPS 2025 Goals, AOU set reduction goals based on a lifecycle assessment to reduce carbon emissions by up to 6.5 million tonnes CO2e cumulatively by 2025.

- As of 2018, AUO was 79.1% of the way to reaching their 2020 goal with 2% attributed to green transport and logistics, 32% attributed to green manufacturing, and 66% attributed to product innovation.
- In 2018, AUO began incorporating downstream transportation and distribution into their GHG inventory. They estimated total emissions to be 69,525 Mt CO_2e, which includes product weight per trip, distance traveled, and mode of transport. These emissions will be tracked in further GHG inventories.
- In 2018, the Green Production Team under the Green Manufacturing Subcommittee implemented 698 projects and achieved 96,450 MWh electricity saved. In total, these projected helped avoid 53,433 metric tons of CO_2e emissions.

Participation in Broader F-GHG Reduction Efforts

- AUO is a member of Taiwan's TFT-LCD Association (TTLA). The TTLA participates on behalf of Taiwan's LCD suppliers in the World Display device Industry Cooperation (WDICC), whose members have agreed to 30% F-GHG emission reductions by 2020 relative to 2010 levels.
- AUO participates in the Product Attribute to Impact Algorithm (PAIA) Project to develop lifecycle impact calculation tools for LCDs, capturing F-GHG emissions information. AUO has employed a methodology to manufacture low-carbon LCD products, including 15.6" notebook panels, 65" and 55" curve panels, and 18.5" to 24" desktop monitors.
- AUO has engaged in developing the SF_6 abatement verification methodology for LCD industries in Taiwan.
- AUO received 9.56 million tons of tradeable carbon credits by the Taiwan EPA for its early action on PFC reductions and third-party verification of its F-GHG abatement. In both 2016 and 2017, AUO signed the largest carbon credit trading deals in Taiwan. A total of 5 million tons were traded through the Taiwan EPA's domestic carbon trading platform in both years.
- AUO carbon credit assets were used to promote carbon neutrality and reduction. As of 2018, a total of 6 companies' building and activity carbon neutrality projects have been completed along with 15 carbon neutrality applications from external non-profit organizations.

DNV·GL

VERIFICATION STATEMENT OF GREENHOUSE GAS ASSERTIONS

Statement No.:
00030-2019-AG-TWN

Issued date:
30 May, 2019

This is to verify initiate reporting of Greenhouse Gas Inventory Management Report (2018) of

AU Optronics Corporation

Scope of Verification
DNV GL Business Assurance (DNV GL) has been commissioned by AU Optronics Corporation to perform a verification of the greenhouse gas assertion of Greenhouse Gas Inventory Management Report (2018) (hereafter the "Inventory Report") with respect to the sites listed in Appendix.

Verification Criteria and GHG Programme
The verification was performed on the basis of ISO 14064-1:2006 and CNS 14064-1: 2006, as well as IPCC 2006 Tier 2b methodology for fluorinated GHG emissions inventory, given to provide for consistent GHG emission identification, calculation, monitoring and reporting.

Verification Statement
It is DNV GL's opinion that with reasonable assurance the greenhouse gas assertion of the Inventory and Inventory Report of April 11, 2019 (version V2) from material discrepancies in accordance with ISO 14064-1:2006 and CNS 14064-1:2006. DNV GL thus requests the registration of the Inventory Report as a GHG inventory demonstration project.

Sophia Kim

GHG Verifier

Place and date:
Taipei, 30 May, 2019

For the issuing office:
DNV GL Business Assurance Co., Ltd.
29Fl., No. 293, Sec. 2, Wenhua Rd., Banqiao District, New Taipei City 220, Taiwan

Management Representative

Sources

AUO 2018 Corporate Social Responsibility Report. Available at https://www.auo.com/en-global/Report_and_Certificate/index?category=CSR_report&series=CSR_report_2018

AUO 2017 Corporate Social Responsibility Report. Available at https://www.auo.com/en-global/Report_and_Certificate/index?category=CSR_report&series=CSR_report_2017

AUO 2016 Corporate Social Responsibility Report. Available at http://www.auo.com.tw/en-global/Report_and_Certificate/download/1164

AUO 2015 Corporate Social Responsibility Report (Section 4.2.1, page 82). Available at http://www.auo.com/upload/download/1/2015_CSR_All_en.pdf.

AUO 2013 Corporate Social Responsibility Report (Section 4.2.1, page 61) Available at http://www.auo.com/upload/download/1/AUO_2013_CSR_EN_All.pdf.

AUO 2011 Corporate Social Responsibility Report.

AUO's responses to the 2019 Carbon Disclosure Project Investor Questionnaire.

AUO's responses to the 2018 Carbon Disclosure Project Investor Questionnaire.

AUO's responses to the 2017 Carbon Disclosure Project Investor Questionnaire.

AUO's responses to the 2016 Carbon Disclosure Project Investor Questionnaire.

AUO's responses to the 2015 Carbon Disclosure Project Investor Questionnaire.

AUO's responses to the 2014 Carbon Disclosure Project Investor Questionnaire.

AUO direct communications.

EPA Greenhouse Gas Equivalencies Calculator. Available at https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator.

Taiwan Environmental Protection Administration. "The Initiative and Efforts from Electronic Corporations in Taiwan- Semiconductor and TFT-LCD." Available at http://unfccc.epa.gov.tw/unfccc/english/_uploads/downloads/05_The_Initiative_and_Efforts_form_Electronic_Industry_in_Taiwan.pdf.

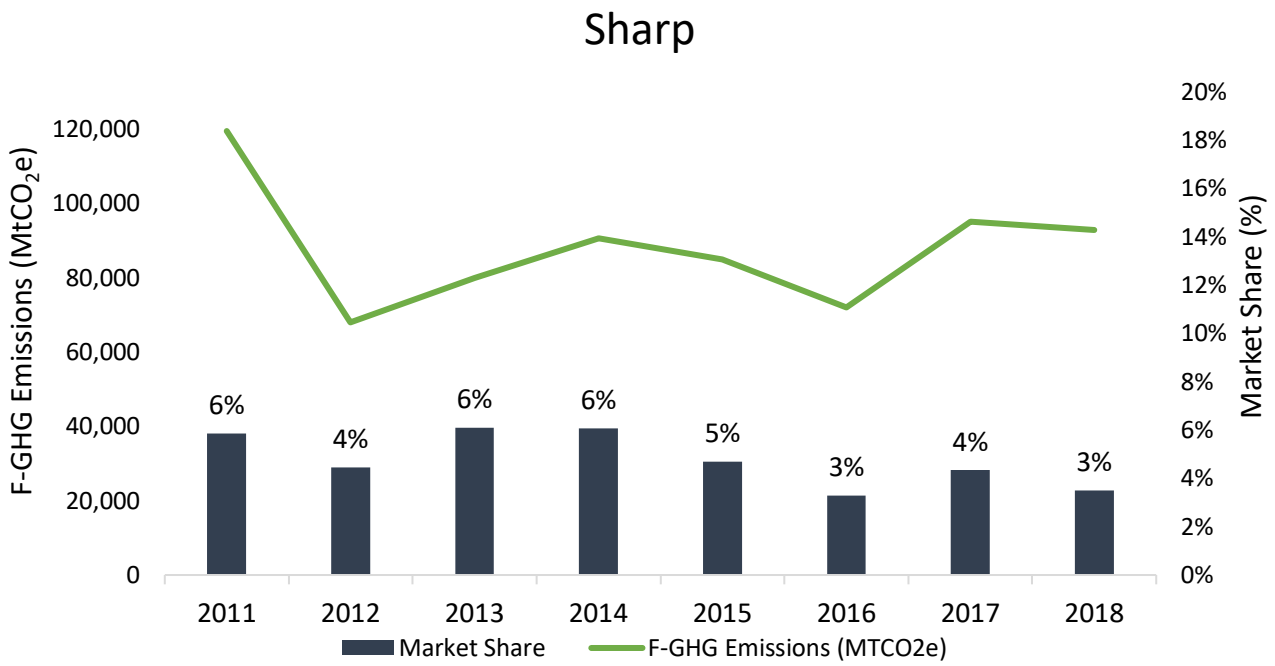
TTLA presentation at APEC meeting, August 2012, Taiwan.

World Display device Industry Cooperation Committee Environmental Report. Available at http://home.jeita.or.jp/device/committee/pdf/Environmental%20Report_ENG_161110.pdf.

Sharp 2018 Data

3% Market Share

F-GHG Emissions Over Time



The chart above shows the following separate but related metrics:

- ***Market share** over time shows the size of the supplier relative to all suppliers in the industry based on area of panels produced.*
- ***Total emissions** over time show total F-GHGs emitted by the supplier each year. Supplier emissions can change due to the implementation of emissions reduction efforts, an increase or decrease in panel production, and/or LCD technology advancements.*
- ***Emission intensity**, noted where data is available, is a measure of the amount of F-GHG emissions per unit of production. Trends in emission intensity show whether the supplier's rate of emissions is increasing or decreasing over time and can indicate whether the supplier is implementing emission reduction efforts. Sharp does not publicly report F-GHG emission intensity.*

F-GHG emissions are publicly reported by suppliers through the CDP (formerly "Carbon Disclosure Project") and/or corporate sustainability reports. In this graph market share is calculated based on production data from IHS Technology.

F-GHG Emissions Reduction Activities

Overview

- In 2018, Sharp emitted a total of approximately 92,833metric tons of CO_2 equivalent ($MtCO_2e$) of F-GHGs, as follows:[11,12]
    - HFCs: 3,845 $MtCO_2e$
    - PFCs: 48,352 $MtCO_2e$
    - SF_6: 31,780 $MtCO_2e$
    - NF_3: 8,856 $MtCO_2e$

Gases Targeted

- SF_6
- PFCs (CF_4, C_2F_6, C_4F_8)
- HFCs (CHF_3)
- NF_3

Processes Targeted

- Etching
- Cleaning

Approaches Used

Abatement

- **Abatement Systems:** Sharp has installed abatement systems on all etching and cleaning process equipment.
- **Scrubbers and Exhaust Treatment:** Sharp has installed scrubbers and exhaust gas treatment systems.

Process Improvements

- **Researching Process Optimization:** Sharp has been researching ways to improve process optimization and manufacturing process conditions at the time that manufacturing equipment is first installed and in daily operations.

Alternative Chemicals

- **Researching Lower GWP Gases:** Sharp has been collecting the latest information from relevant sources and researching the possibility of using lower GWP alternative gases.

Emissions Measurement Approaches and Verification

- Sharp estimates F-GHG emissions based on the Tier 2b method for electronics industry emissions provided in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.
- Sharp's reported Scope 1 emissions, which include F-GHGs, have not undergone third party verification.

[11] Sharp reports annual emissions for its fiscal year, April 1 through March 31, rather than calendar year.
[12] Reported F-GHG emissions may include production of LCDs and other electronic products.

Emission Reduction Goals and Progress

- Sharp works to reduce F-GHG emissions in accordance with the targets of Ministry of Economy, Trade and Industry; the Japan Electronics and Information Technology Industries Association (JEITA); and other industrial associations.
- Sharp set a goal to reduce annual GHG emissions to below 2007 baseline emissions levels for ten manufacturing fabrication facilities (fabs) by 2011.
- Sharp set a goal to reduce GHG emissions intensity per adjusted production unit (tons of CO_2e/100 million yen) by 35% across the ten fabs by 2012. By end of fiscal year 2011, Sharp met both of its goals and reduced total emissions by 40% and emissions intensity by 42%.
- In fiscal year 2018, the Sharp Group's GHG emissions increased by 14.6% compared to the previous fiscal year due to an expansion of the tabulation range resulting from the acquisition of a subsidiary.

Sources

Japan Electronics and Information Technology Industries Association (JEITA). See http://www.jeita.or.jp/english/.

Nishida, et al. PFC Emission Reduction Strategy for the LCD Industry. Journal of the SID 13/10. 2005

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Sharp Corporation's responses to the 2019 Carbon Disclosure Project Investor Questionnaire.

Sharp Corporation's responses to the 2018 Carbon Disclosure Project Investor Questionnaire.

Sharp Corporation's responses to the 2017 Carbon Disclosure Project Investor Questionnaire.

Sustainability Report 2019 by the Sharp Corporation. Available at: https://global.sharp/corporate/eco/report/ssr/pdf/ssr2019_e.pdf

Sustainability Report 2018 by the Sharp Corporation. Available at: http://www.sharp-world.com/corporate/eco/report/ssr/pdf/ssr2018e.pdf

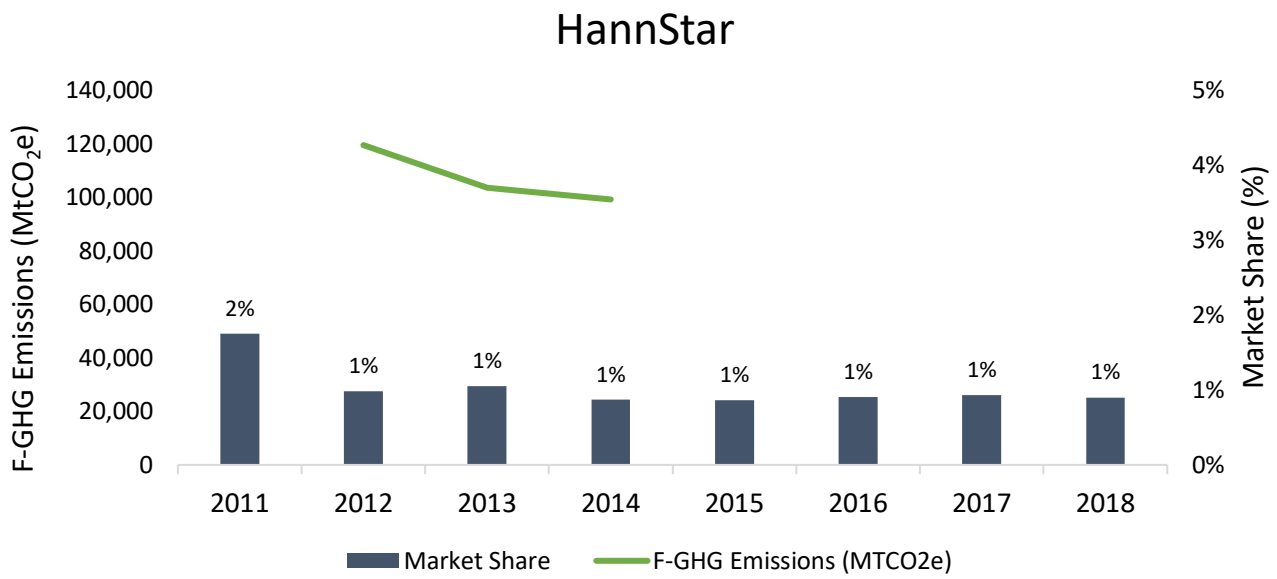
Sustainability Report 2017 by the Sharp Corporation. Available at: http://www.sharp-world.com/corporate/eco/report/ssr/pdf/ssr2017e.pdf

Sustainability Report 2016 by the Sharp Corporation. Available at: http://www.sharp.co.jp/corporate/eco/report/ssr/index.html.

HannStar 2018 Data

1% Market Share

F-GHG Emissions Over Time



The chart above shows the following separate but related metrics:

- ***Market share** over time shows the size of the supplier relative to all suppliers in the industry based on area of panels produced.*
- ***Total emissions** over time show total F-GHGs emitted by the supplier each year. Supplier emissions can change due to the implementation of emissions reduction efforts, an increase or decrease in panel production, and/or LCD technology advancements.*
- ***Emission intensity**, noted where data is available, is a measure of the amount of F-GHG emissions per unit of production. Trends in emission intensity show whether the supplier's rate of emissions is increasing or decreasing over time and can indicate whether the supplier is implementing emission reduction efforts. HannStar does not publicly report F-GHG emissions but does report total GHG emission intensity, as noted in the section below.*

F-GHG emissions are publicly reported by suppliers through the CDP (formerly "Carbon Disclosure Project") and/or corporate sustainability reports. In this graph, market share is calculated based on production data from IHS Technology.

F-GHG Emission Reduction Activities

Overview

- HannStar did not report total F-GHG emissions in 2018.
- In 2018, HannStar reduced F-GHG emissions about 39,039MtCO2e by abatement equipment.
- In 2018, F-GHGs emissions made up 24.55% of total GHG emissions, an improvement from 2017 (26.42%).

Emissions Intensity:

- HannStar's GHG emission intensity decreased from 0.077 $MtCO_2e/m^2$ in 2017 to 0.073 $MtCO_2e/m^2$ in 2018.

Gases Targeted

- SF_6
- NF_3

Processes Targeted

- Etching
- Cleaning

Approaches Used

Abatement

- Hannstar has installed the thermal abatement to remove F-GHGs emission at thin film process and new etching equipment.

Alternative Chemicals

- HannStar is using lower GWP gases, where possible. Additional details not available.

Emissions Measurement Approaches and Verification

- HannStar estimates F-GHG emissions based on the Tier 2b method for electronics industry emissions provided in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.
- HannStar's plants in Taiwan have been developing GHG inventories and implementing third party verification with reference to ISO 14064-1 since 2005.

Emission Reduction Goals and Progress

- Since HannStar's GHG emissions are mostly due to electricity consumption and the use of F-GHGs in flat panel display manufacturing, the company has focused its GHG reduction efforts on these two areas.
- HannStar applied for GHG early action offset credits based on the Taiwan EPA's Principles for Promoting Greenhouse Gas Pilot and Offset Projects and the Announced GHG Emission Intensity for TFT-LCD Industry.
- In 2015, Taiwan's EPA awarded Hannstar 3.78 million tons of carbon credits for their early action in voluntary GHG reductions.

Participation in Broader F-GHG Reduction Efforts

HannStar is a member of Taiwan's TFT-LCD Association (TTLA). The TTLA participates on behalf of Taiwan's LCD suppliers in the World Display device Industry Cooperation (WDICC), whose members have agreed to 30% F-GHG emission reductions by 2020 relative to 2010 levels.

Sources

HannStar "SF_6 Abatement Strategy in Taiwan". Presentation by Taiwan's Industrial Technology Research Institute (ITRI), 2004. Available at: https://www.epa.gov/sites/production/files/2016-02/documents/conf04_lu.pdf.

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World Display device Industry Cooperation Committee Environmental Report. Available at http://home.jeita.or.jp/device/committee/pdf/Environmental%20Report_ENG_161110.pdf.

HannStar 2017 Corporate Sustainability Report (page 27). Available at https://www.hannstar.com/Common.aspx?mid=24&tmid=6&modid=1

Suppliers with Recent Public Data, but Without Public Data in 2018

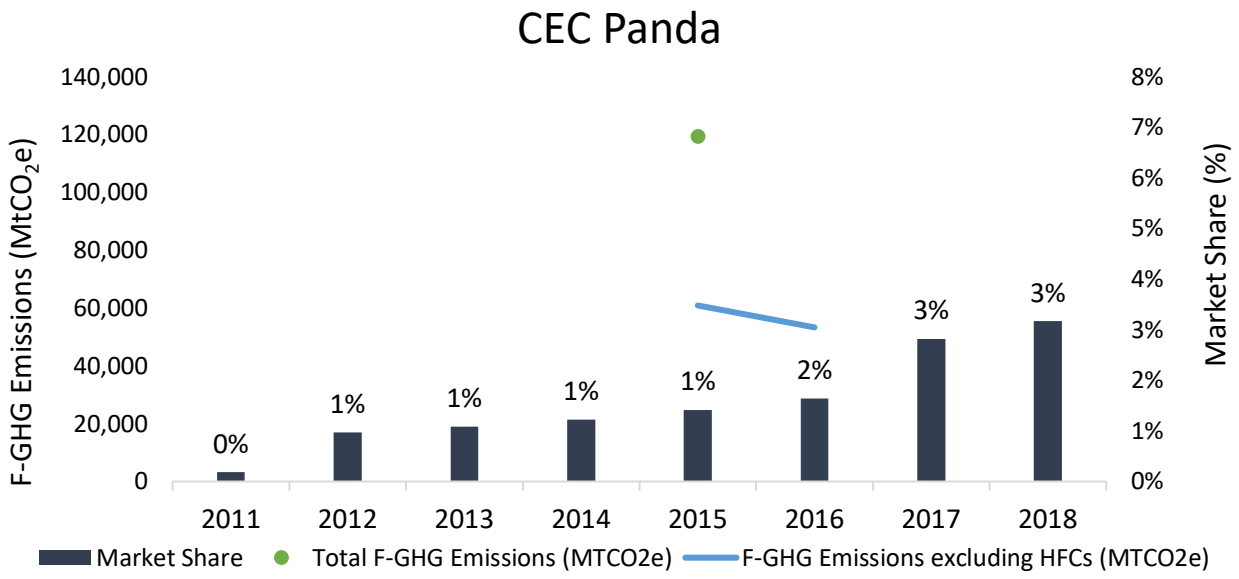
CEC Panda and Chunghwa Picture Tubes (CPT) did not publicly report F-GHG emissions data, F-GHG reduction goals, or progress towards reduction goals in 2018, but have reported F-GHG related information within the last two years. Though 2018 data is missing, some recent historical data is available on the following suppliers' F-GHG emission reduction activities, including on gases and processes targeted and F-GHG emission reduction approaches.

Below, the suppliers are listed based on their 2018 market share:

CEC Panda 2018 Data

3% Market Share

F-GHG Emissions Over Time



The chart above shows the following separate but related metrics:

- ***Market share*** *over time shows the size of the supplier relative to all suppliers in the industry based on area of panels produced.*
- ***Total emissions*** *over time show total F-GHGs emitted by the supplier each year. Supplier emissions can change due to the implementation of emissions reduction efforts, an increase or decrease in panel production, and/or LCD technology advancements.*

- ***Emission intensity**, noted where data is available, is a measure of the amount of F-GHG emissions per unit of production. Trends in emission intensity show whether the supplier's rate of emissions is increasing or decreasing over time and can indicate whether the supplier is implementing emission reduction efforts. CEC Panda does not publicly report F-GHG emission intensity. Note that CEC Panda reported HFC emissions in 2015, but not in 2016, so the chart above shows F-GHG emissions both including and excluding HFC emissions for comparison between years.*

F-GHG emissions are publicly reported by suppliers through the CDP (formerly "Carbon Disclosure Project") and/or corporate sustainability reports. In this graph, market share is calculated based on production data from IHS Technology.

F-GHG Emission Reduction Activities

Overview

- *No information is available on CEC Panda's 2018 F-GHG emissions.*
- *No information is available on CEC Panda's 2017 F-GHG emissions.*
- In 2016, per its second year of reporting F-GHG emissions to the CDP, CEC Panda emitted a total of approximately 53,312 metric tons of CO_2 equivalent ($MtCO_2e$) of F-GHGs, as follows:[13]
    - PFCs: 2,297 $MtCO_2e$
    - SF_6: 11,082 $MtCO_2e$
    - NF_3: 39,933 $MtCO_2e$

Gases Targeted

No information is available on gases targeted by CEC Panda's F-GHG emission reduction activities.

Processes Targeted

No information is available on processes targeted by CEC Panda's F-GHG emission reduction activities.

Approaches Used

No information is available on approaches used by CEC Panda to reduce F-GHG emissions.

Emissions Measurement Approaches and Verification

- CEC PANDA estimates its F-GHG emissions based on the Tier 2b method provided by the 2006 IPCC Guidelines for National Greenhouse Gas Inventories for electronics industry emissions.
- CEC PANDA has not undergone third party verification or assurance for its reported Scope 1 emissions, which include F-GHG emissions, for its previous years' GHG inventory data.

Emission Reduction Goals and Progress

- CEC Panda set a goal to reduce Scope 2 GHG emissions by 10% from 2015 to 2016 and reported that 100% of the target was achieved in 2016. No information is available on CEC Panda's 2017 progress towards F-GHG emission reduction goals.

[13] CEC Panda reported HFC emissions in 2015 but not 2016 or 2017.

- In 2016, CEC Panda implemented 37 projects to reduce GHG emissions by an estimated annual 7301 CO_2e savings in metric tons CO_2e.

Participation in Broader F-GHG Reduction Efforts

No information is available on CEC Panda's participation in broader F-GHG reduction efforts.

Sources

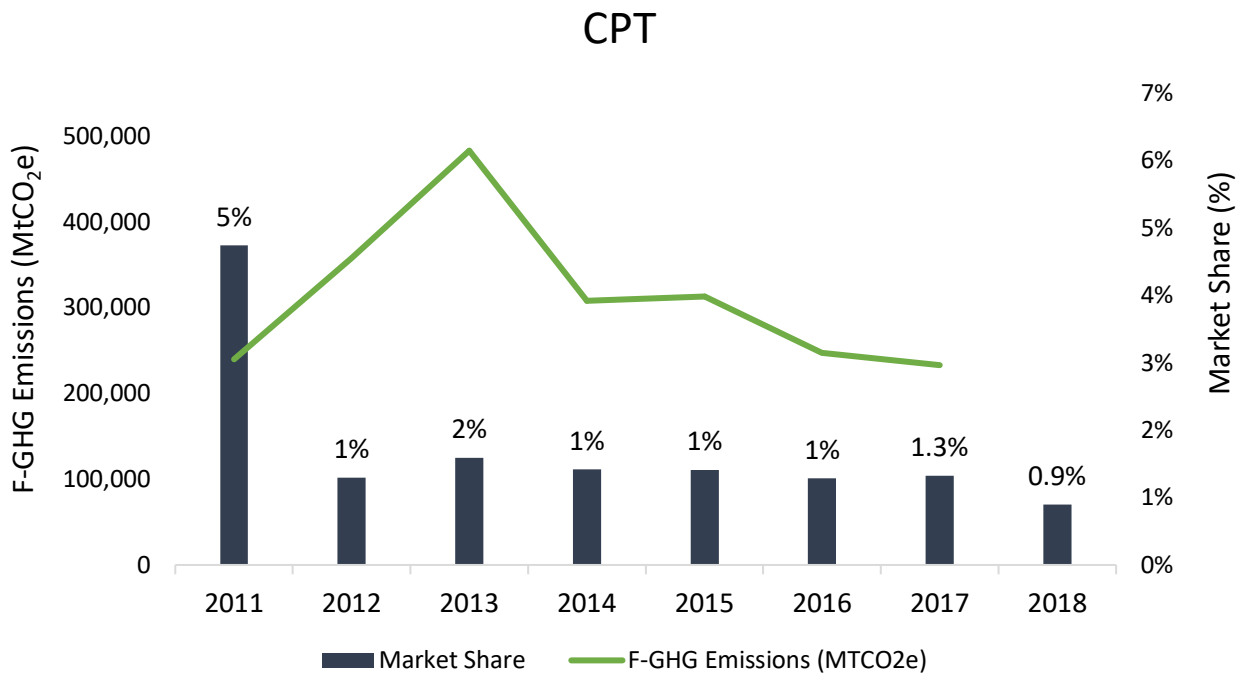
CEC PANDA's responses to the 2017 CDP Investor QuestionnaireCEC PANDA's responses to the 2016 CDP Investor Questionnaire

Chunghwa Picture Tubes (CPT) 2018 Data

1% Market Share

Note: CPT ceased operations in 2019

F-GHG Emissions Over Time



The chart above shows the following separate but related metrics:

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- ***Total emissions** over time show total F-GHGs emitted by the supplier each year. Supplier emissions can change due to the implementation of emissions reduction efforts, an increase or decrease in panel production, and/or LCD technology advancements.*
- ***Emission intensity**, noted where data is available, is a measure of the amount of F-GHG emissions per unit of production. Trends in emission intensity show whether the supplier's rate of emissions is increasing or decreasing over time and can indicate whether the supplier is implementing emission reduction efforts. CPT does not publicly report F-GHG emission intensity.*

F-GHG emissions are publicly reported by suppliers through the CDP (formerly "Carbon Disclosure Project") and/or corporate sustainability reports. In this graph, market share is calculated based on production data from IHS Technology.

F-GHG Emission Reduction Activities

Overview

- CPT's 2018 emissions data are not publicly available. 2018 represents the last full year of CPT operations, as CPT closed in 2019.
- In 2017, PFC emissions accounted for 30.27% of CPTs GHG emissions which were 769,615 $MtCO_2e$. Based on this information, CPTs PFC emissions for 2017 were estimated to be 232,962 $MtCO_2e$, a 5% decrease since 2016.
- In 2016, CPT emitted approximately 247,112 metric tons of CO_2 equivalent ($MtCO_2e$) of F-GHGs, a 55% reduction from 2008, compared to a 49% reduction from 2008 in 2015 (313,000 $MtCO_2e$).
- Between 2002 and 2017, CPT reduced F-GHG emissions by approximately 36.15 million $MtCO_2e$. This is equivalent to removing 7.7 million vehicles from the road for one year.

Gases Targeted

- SF_6
- PFCs
- HFCs
- NF_3

Processes Targeted

- Etching
- Cleaning

Approaches Used

Abatement

- **Abatement Systems:** CPT has installed abatement systems in all newer generation fabrication facilities (fabs).

Process Improvements

- **PFC Reduction:** In 2014, CPT implemented PFC reduction methods and evaluated process equipment, targeting its 4.5 generation fabs, an earlier generation of fabs built prior to 2004. CPT conforms to the WDICC resolution set in 2003 requiring that new plants install F-GHGs treatment facilities.
- **Cleaning Process:** CPT completed reconstruction of the cleaning process in their Taoyuan and Longtan plants, resulting in a 38% emission reduction of fluorinated compounds in 2011 from 2010 levels, equal to approximately 170,000 $MtCO_2e$.

Alternative Chemicals

- **SF_6 Replacement:** CPT is using lower GWP gases, where possible. For example, CPT continues to implement carbon reduction activities by replacing SF_6 with NF_3 in cleaning processes.

Emissions Measurement Approaches and Verification

- CPT estimates its F-GHG emissions based on the Tier 2b method provided by the 2006 IPCC Guidelines for National Greenhouse Gas Inventories for electronics industry emissions.
- CPT's GHG inventory undergoes third-party verification and relies on the ISO14064-1 greenhouse gas management system.

- CPT details their GHG emission reporting requirements under the Regulations Governing GHG Emission Reporting in their Corporate Social Responsibility Report.

Emission Reduction Goals and Progress

- CPT set a goal to reduce GHG emissions by 280,000 $MtCO_2e$ from 2013 to 2016 through process optimization, adoption of dry etch machinery, and installation of tail gas incinerator facilities.
- In 2017, emissions dropped to 769,615 tons CO_2, which represents a decrease by around 411,000 tons CO_2 or 34.82% compared to 2008.
- In 2016, CPT's GHG emissions were 778,618 $MtCO_2e$, an increase from 778, 618 $MtCO_2e$ in 2016. The majority of CPT's GHG emissions are from F-GHG process emissions and electricity use.

Participation in Broader F-GHG Reduction Efforts

- CPT is a member of the Taiwan's TFT-LCD Association (TTLA). The TTLA participates on behalf of Taiwan's LCD suppliers in the World Display device Industry Cooperation (WDICC), whose members have agreed to 30% F-GHG emission reductions by 2020 relative to 2010 levels. CPT will work with TTLA to provide regular emission information of fluorinated compounds and engage in reductions of fluorinated compounds.

Sources

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TTLA presentation at APEC meeting, August 2012, Taiwan.

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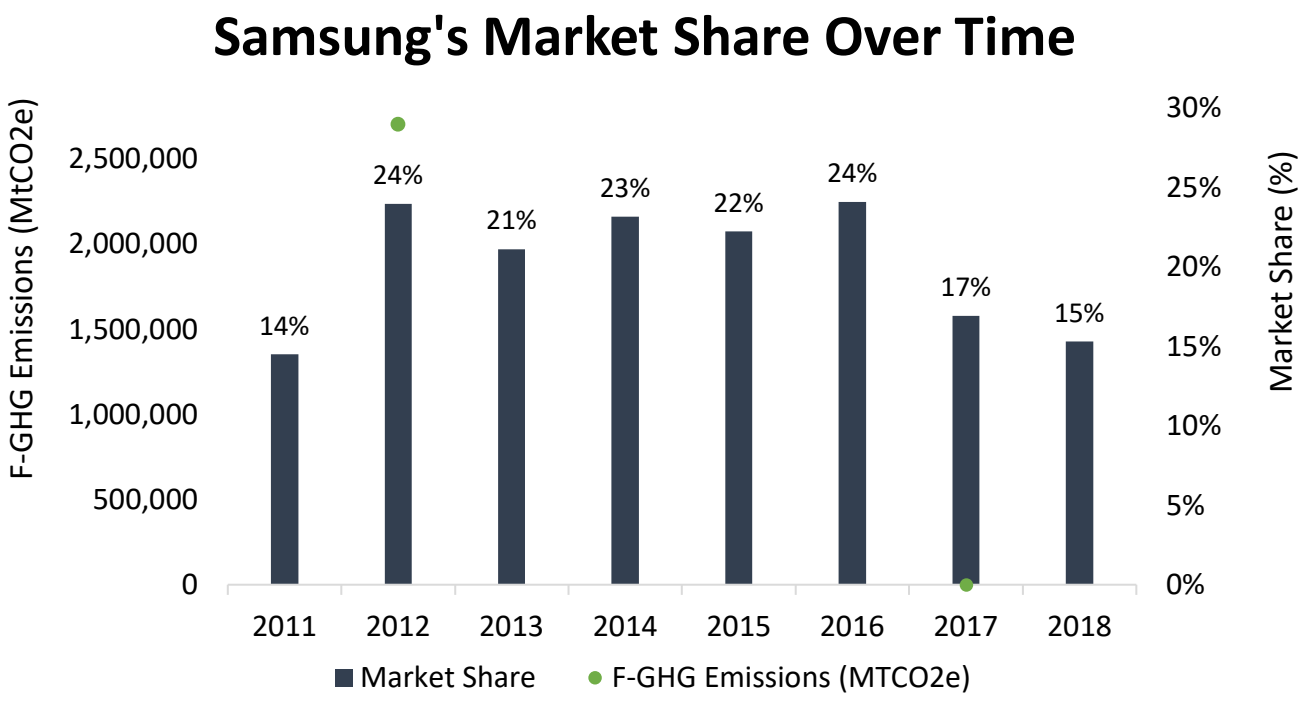
Suppliers Without Public Data in Recent Years

Samsung, China Star, HKC, and Infovision did not report public data in 2018, 2017, or 2016. As a result:

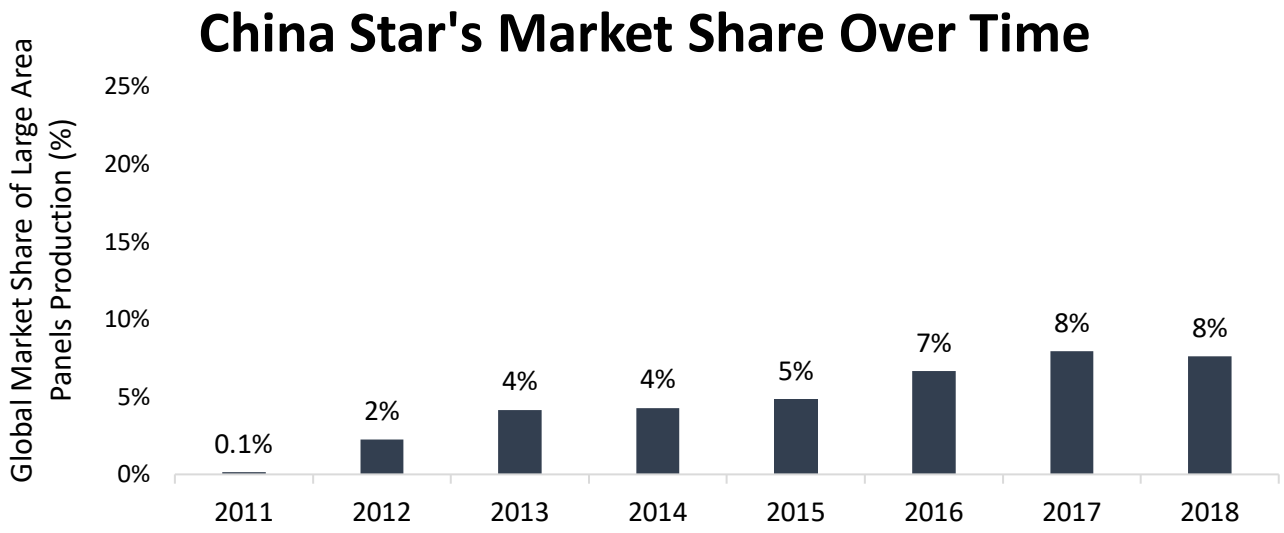
- No information is available on these suppliers' F-GHG emission reduction activities, including on gases targeted, processes targeted, or approaches used.
- These suppliers do not publicly measure or verify F-GHG emissions.
- These suppliers do not have or disclose emission reduction goals and progress.
- No information is available on these suppliers' participation in broader F-GHG reduction efforts, except for Samsung, which is subject to Korea's regulatory requirements (i.e., the Korean Emissions Trading Scheme (K-ETS)) to reduce GHG emissions, though it is unclear if they are actively participating.

Below, the suppliers are listed based on their 2018 market share:

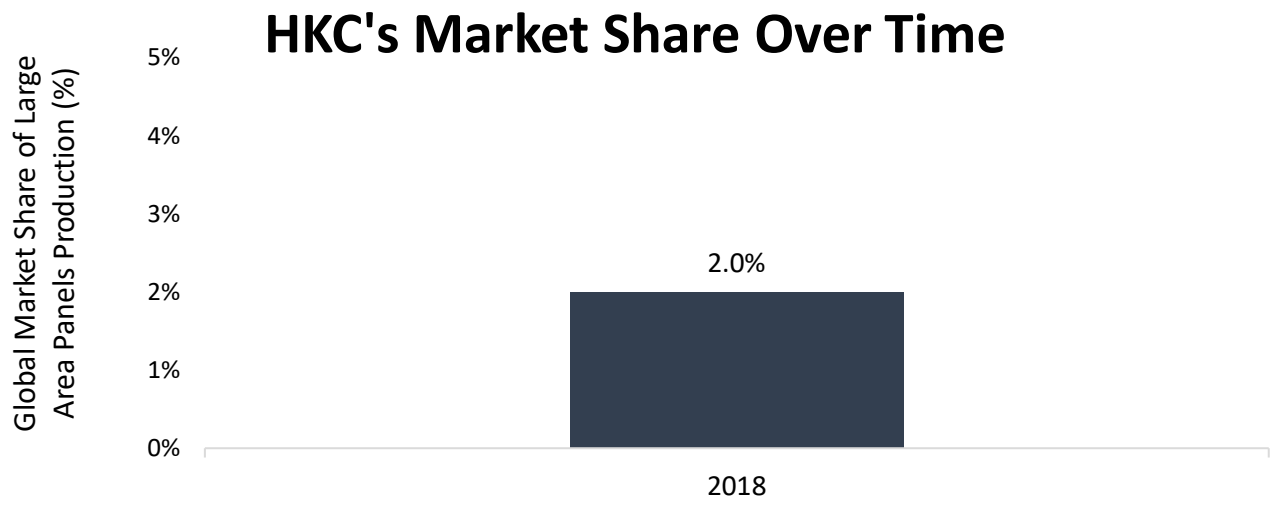
Samsung Display



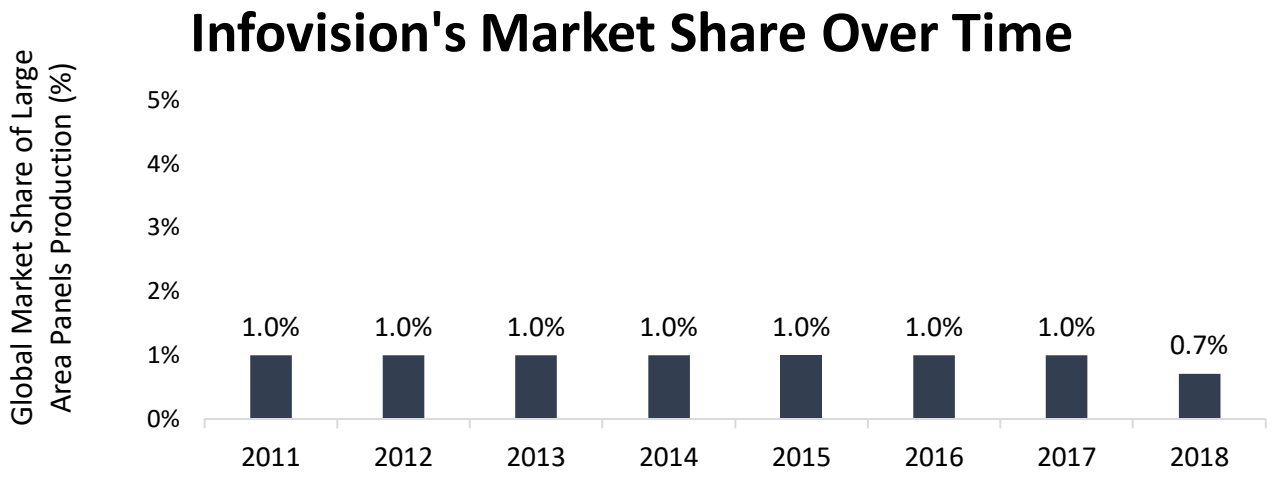
China Star



HKC



Infovision


Infovision's Market Share Over Time
Global Market Share of Large Area Panels Production (%)
5%
4%
3%
2%
1%
0%
1.0%
1.0%
1.0%
1.0%
1.0%
1.0%
1.0%
0.7%
2011
2012
2013
2014
2015
2016
2017
2018