

F-GHG Emissions Reduction Efforts: 2017 Supplier Profiles

U.S. Environmental Protection Agency
Office of Air and Radiation
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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 5 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 2017, 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.

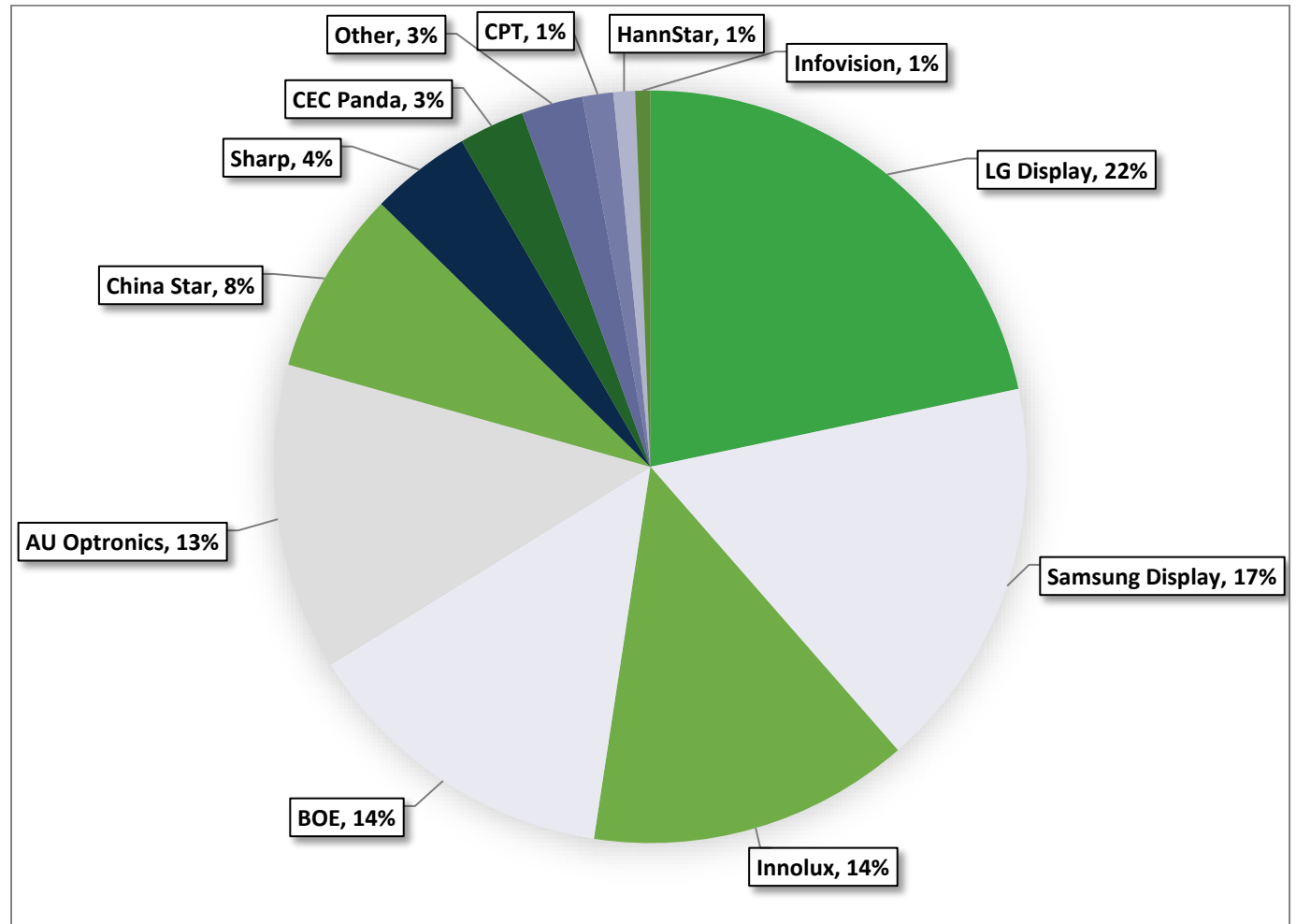
Following the summary information, individual profiles provide more information on specific methods, such as abatement, process optimization and use of alternatives that suppliers are using to reduce their F-GHG emissions.

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 eleven-global flat panel display suppliers named among the profiles produce 97%² of all large-area flat panel displays sold globally, as shown in the chart below³. Large area panels are defined as being 9.1 inches or larger.

2017 Global Market Share of Large Area Panels Production for Featured Suppliers



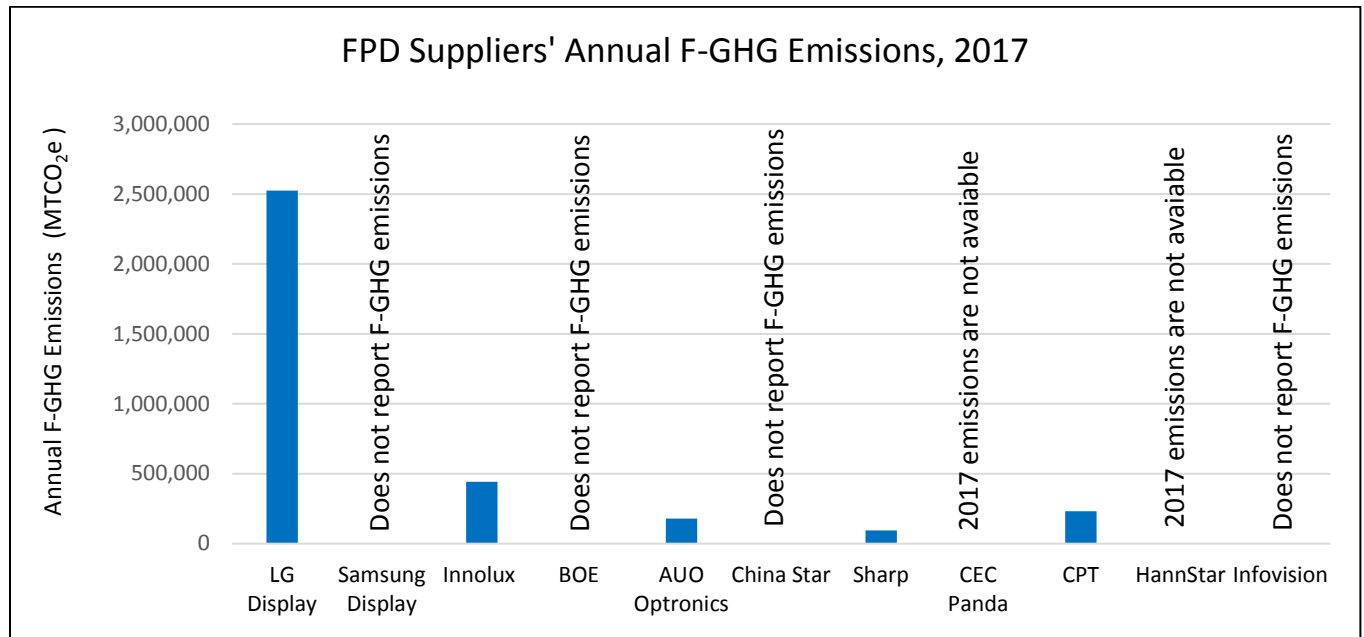
Source: IHS Technology 2017. "Large Area Display Production Strategy Tracker."

² Source: IHS Technology 2017. "Large Area Display Production Strategy Tracker."

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

Key Findings Based on 2017 Data

- Some suppliers who previously reported annual F-GHG emissions did not provide this data for their 2017 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 alternative F-GHGs in key processes. This will better equip brands to understand all methods their suppliers implement to reduce F-GHG emissions. For example, LG Display provides information on the alternative use of NF_3 to replace SF_6 in the etch process, with demonstrated emissions reduction potential. While LG Display uses NF_3 in remote plasma source chamber clean (RPSC) in all its manufacturing lines, it has replaced NF_3 with F_2 in chamber cleaning for one of its manufacturing lines. It would be helpful to learn the extent to which such alternative uses for existing F-gases and/or any new gases used also necessitate installation of F-GHG abatement technologies to mitigate emissions. An optimal F-GHG emission intensity, based on full abatement and/or the fullest use of alternative gases, could serve as an indicator on whether F-GHG emission reduction efforts have been implemented to the fullest extent possible.



Note: CEC Panda reported emissions in 2016 but not 2017. HannStar provides some details on its F-GHG emissions reduction efforts, but does not provide its actual 2017 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.

Summary of F-GHG reporting reduction activities by LCD supplier

Company	Market Share of FPD Production	Publicly Reported 2017 F-GHGs	2017 F-GHG Emissions (MtCO _{2e})	% Reduction from 2016	2017 F-GHG Intensity (MtCO _{2e} /m ² of panel produced)	GHG Reduction Goals ⁴	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)
LG Display	22%	✓	2,525,243	NA	Not Available	12.60% by 2020	✓	✓	✓	✓	not used	✓	✓	✓	F-GHGs not used	✓	✓	✓				
Samsung	17%	2017 F-GHG emissions data is not publicly available.																				
Innolux	14%	✓	384,572	7%	0.0052	No	✓	✓	✓	✓	✓	✓	✓	✓	not inventoried	✓	✓			✓	✓	
AU Optronics	13%	✓	180,092	-22%	0.0026	25% by 2015	✓	✓	✓	CF ₄	✓	✓	✓	✓	deemed too minor	✓	✓			✓	✓	
BOE	14%	2017 F-GHG emissions data is not publicly available, however information on general GHG emissions management efforts is publicly available.																				
China Star	8%	2017 F-GHG emissions data is not publicly available.																				
Sharp	4%	✓	95,125	-32%	Not Available	No		✓	✓	CF ₄ C ₂ F ₆ C ₄ F ₈	CHF ₃	✓	✓	✓	no info available	✓	✓		✓	✓	✓	
CEC Panda	3%	2017 F-GHG emissions data is not publicly available.																				
CPT ⁵	1%	✓	232,962	6%	Not Available	280,000 MtCO _{2e} by 2016		✓	✓	✓	✓	✓	✓	✓	no info available	✓	✓			✓		
HannStar	1%		Not Available	NA	Not Available	No	✓	✓	✓	✓		✓	✓	✓	F-GHGs not used	✓	✓			✓		
Infovision	1%	2017 F-GHG emissions data is not publicly available.																				

⁴ For more information on GHG emission reduction goals, including the base year and scope of included emissions, see the individual Supplier Profiles.

⁵ Estimated using publicly available information.

Flat Panel Display Supplier Profiles

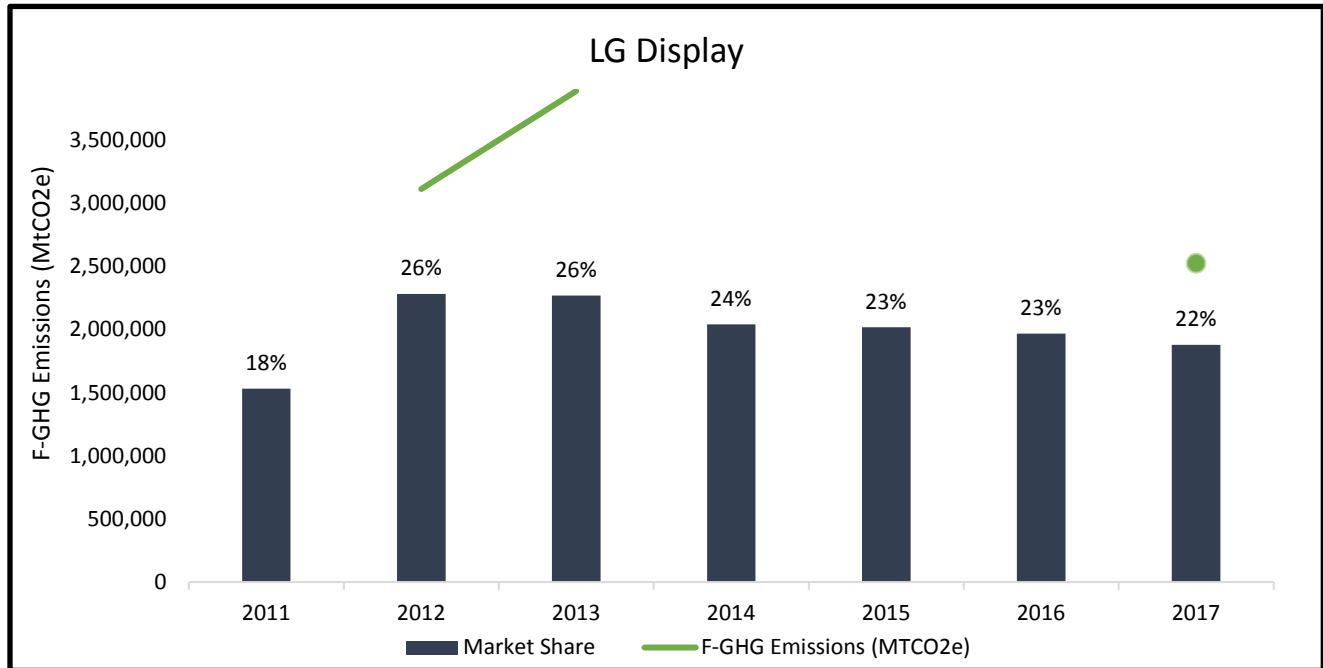
Flat panel display suppliers are presented in descending order of market share.

LG Display	7
Innolux Corporation	11
AUO (AU Optronics)	15
Sharp	21
CEC Panda	24
Chunghwa Picture Tubes (CPT)	26
HannStar	29
Suppliers Without Public Data	32
Samsung	32
BOE	33
China Star	33
Infovision	34

LG Display 2017 Data

22% 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-GHG's 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 2017, LG Display emitted approximately 2,525,243 MtCO₂e of F-GHG's as follows:
 - HFCs: 265 MtCO₂e
 - PFCs: 131,560 MtCO₂e

- SF₆: 2,393,418 MtCO₂e

Gases Targeted

- SF₆
- PFCs
- NF₃

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 NF₃ in cleaning tools and combustion-type centralized systems are installed for SF₆ 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

- **SF₆ Replacement:** In 2014, LG Display developed a gas application technology as an alternative to using SF₆ and has started implementing the use of the alternative. In 2015, since joining the Korean emission trading scheme, LG Display replaced SF₆ as a process gas used in dry etching with NF₃, which has a lower GWP. At its Paju, Korea plant, the use of SF₆ in 2017 decreased by 44% from 2015 levels.
- **Remote Plasma Source Chamber Clean:** LG Display has applied NF₃ remote plasma source chamber clean (RPSC) to all manufacturing lines. RPSC's utilization rate is 97% compared to 70% for an ordinary chamber.
- **NF₃ Replacement:** LG Display has replaced NF₃ with F₂ in chamber cleaning on one of its manufacturing lines. LG Display continues to research alternative lower GWP etching gases than SF₆ for the dry etching process.
- LGD invested 3.8 billion won (₩) (in 2016, 1 ₩ = 0.00088 USD⁶) for the development of clean production technology to replace SF₆ to respond to the greenhouse gas emissions trading scheme. Currently, SF₆ 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.

Emissions Measurement Approaches and Verification

- LG Display uses national GHG emission estimation guidelines issued by the South Korean Ministry of Environment and estimates NF₃ emissions by using the [2006 Intergovernmental Panel on Climate Change \(IPCC\) Guidelines for National Greenhouse Gas Inventories](#) Tier 2b guidelines.

⁶ Source: xe.com. Accessed on 18th April 2019

- LG Display uses the CDM methodology AM0065 as the verification criteria for their SF₆ replacement processes since the methodology. This verification occurs once per year, and applies to domestic facilities which have replaced SF₆ with NF₃.
- LG Display's GHG emissions are verified by a third party in accordance with South Korean government regulations. NF₃ 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 12.6% by 2020, 16.8% by 2022 and 54.6% by 2040, relative to 2014 levels. Scope 1 emissions include F-GHG.
- LG Display reduced GHG emissions by 21.8% in 2017 compared to 2016 through process gas replacement and energy saving campaigns. At its Paju plant, LG Display reduced the use of SF₆ in 2017 by 44% through the alternative use of NF₃.
- 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 \(KDIA\)](http://www.kdia.org), 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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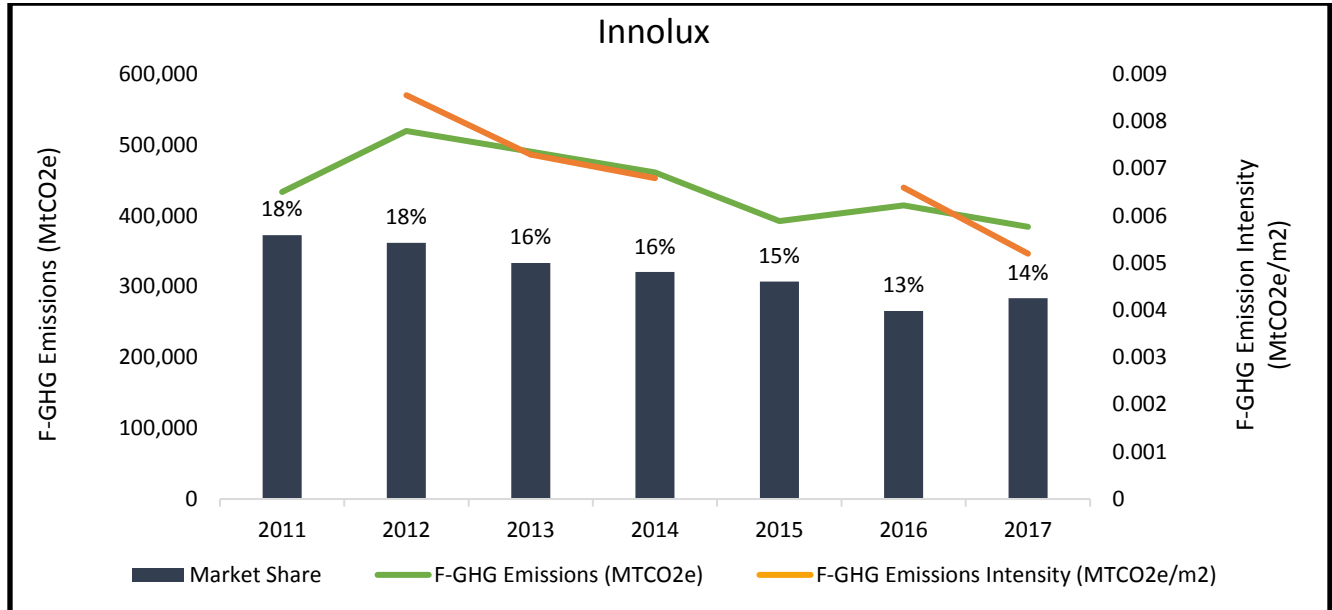
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“Republic of Korea: An Emissions Trading Case Study.” Environmental Defense Fund, Climate Change Research Institute of Korea, and IETA. Available at http://www.ieta.org/resources/2016%20Case%20Studies/Korean_Case_Study_2016.pdf.

Innolux Corporation 2017 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.

F-GHG Emission Reduction Activities

Overview

- In 2017, Innolux emitted approximately 384,572 metric tons of CO₂ equivalent (MtCO₂e) of F-GHGs, as follows:
 - HFCs: 30,829 MtCO₂e

- PFCs (includes NF₃): 50,858⁷ MtCO₂e (48,462 MtCO₂e (NF₃) + 2,396 MtCO₂e (PFCs))
- SF₆: 302,886 MtCO₂e
- In 2017, Innolux reported that removal equipment reduced total annual F-GHG emissions by 3,029,691 MtCO₂e, compared to 2,865,222 MtCO₂e reduced in 2016, and 2,139,043 MtCO₂e reduced in 2015.
- In 2017, F-GHGs represented 10.6 percent of Innolux's total GHG emissions compared to 12.8 percent of total emissions in 2016.⁸

Emissions Intensity:

- Innolux reduced its F-GHG emission intensity from 0.0094 MtCO₂e/m² of panel produced in 2010 to 0.0086 MtCO₂e/m² in 2012.
- In 2013 it dropped to 0.0073 MtCO₂e/m².
- In 2014, Innolux's F-GHG emission intensity was 0.0068 MtCO₂e/m² of glass panels.
- Innolux continued to achieve its goal to further reduce its F-GHG emission intensity to 0.0066 MtCO₂e/m² in 2016.
- In 2017, the F-GHG emission intensity per input substrate at the TFT-LCD stage of Taiwan sites was 0.0052 MtCO₂e/m², which was reduced 12.5% compared with 2016.

Gases Targeted

- | | |
|-------------------|-------------------|
| ● SF ₆ | ● HFCs |
| ● PFCs | ● 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 2017.*

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 SF₆ emitted during the etching process by combustion.
- Innolux has installed local combustion scrubbers. In 2017, Innolux reduced 3,029,691 MtCO₂e of F-GHGs.

⁸ In 2017, Innolux's total Scope 1 emissions accounted for 12.15% of their total emissions, meaning F-GHG emissions make up the majority of Innolux's Scope 1 emissions.

Process Improvements

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

Gas Recycling/Reuse

- **Recovery System:** Innolux is working with the Industrial Technology Research Institute of Taiwan to test an SF₆ liquefaction recovery system. If it works, Innolux will expand the system across applicable fabs.

Alternative Chemicals

- **SF₆ Replacement:** Innolux has planned to replace SF₆ with NF₃ 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.
- 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 2017, Innolux audited the carbon emissions of 82 suppliers, who inventoried their GHG emissions. Innolux exceeded its 2017 target of reducing carbon emission of suppliers by 133,100 MtCO₂e and achieved a reduction of 133,971 MtCO₂e.
- 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 CO₂e per year.

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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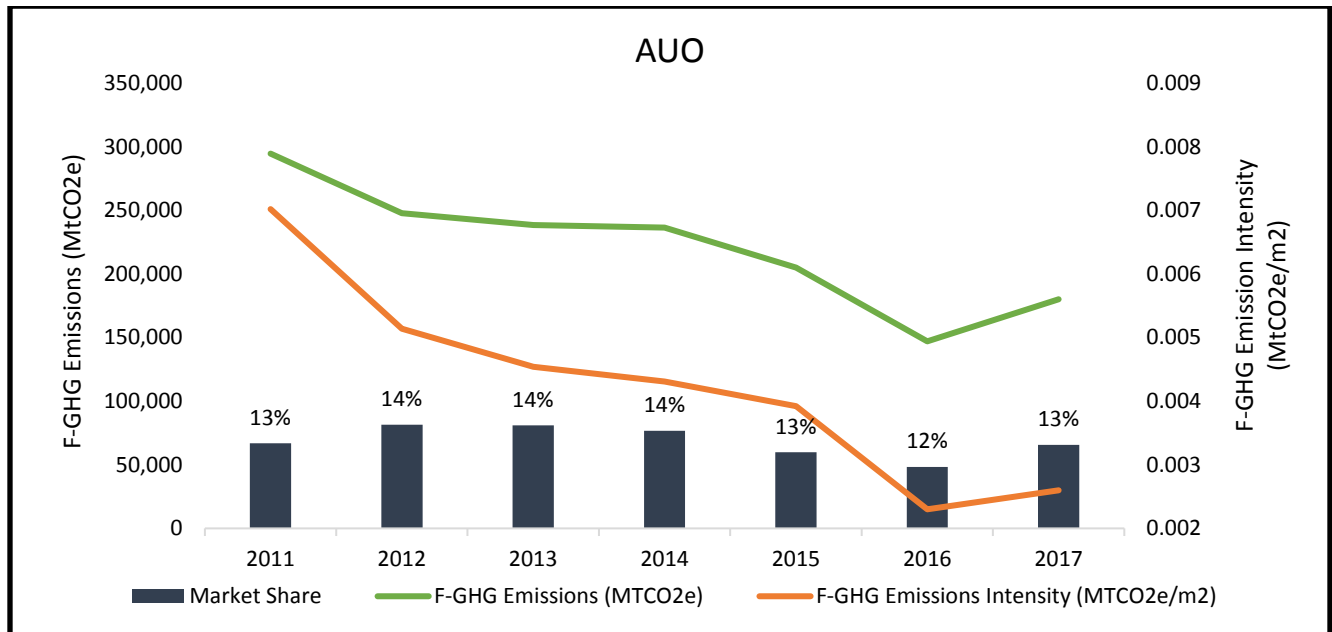
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AUO (AU Optronics) FY 2017 Data

13% 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.

F-GHG Emission Reduction Activities

Overview

- In 2017, AUO emitted approximately 180,092 metric tons of CO₂ equivalent (MtCO₂e) of F-GHGs, as follows:
 - HFCs: 9,634 MtCO₂e
 - PFCs (includes NF₃): 24,884 MtCO₂e (22,154 MtCO₂e (NF₃) + 2,690 MtCO₂e (PFCs))

- SF₆: 145,574 MtCO₂e
- From 2003 to 2017, AUO reduced total F-GHG emissions by 14.7 million metric tons CO₂e. This is equivalent to taking 3.1 million cars off the road for one year.⁹

Emissions Intensity:

- In 2017, the F-GHG emission intensity was 0.0026 MtCO₂e/m², a 13% increase since 2016.
- The direct GHG emission intensity for Scope 1 was 4.8 kgCO₂e/m² (which translates to 0.0048 MtCO₂e/m²) a 12% increase compared to that of 2016. The corresponding indirect GHG emissions intensity for Scope 2 was 46.4 kgCO₂e/m² (0.0046 MtCO₂e/m²), a 3% increase compared to that of 2016. Thus, the combined GHG emission intensity for both Scope 1 and Scope 2 was approximately 51.0 kg CO₂e/m² (0.051 MtCO₂e/m²).
- From 2010 to 2017, AUO reduced its GHG emissions intensity, which includes both Scope 1 and Scope 2 GHG emissions, by 13%, from 58.5 kg CO₂e/m² (0.059 MtCO₂e/m²) of panel produced to 51.0 kg CO₂e/m² (0.051 MtCO₂e/m²). Since 2008, AUO has reduced the Scope 1 and Scope 2 GHG emissions per unit area of production by 45%.
- 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 | • HFCs |
| • PFCs (specifically CF ₄) | • 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 SF₆ Consumption:** AUO's process experts worked with its SF₆ supplier to implement ways to reduce the quantity of SF₆ used in etching across all fabs. At one of its fabs, at full production capacity,

⁹ Calculated using EPA's Greenhouse Gas Equivalencies Calculator, which is available at <https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator>

adjusting relevant SF₆ process parameters can result in reducing the equivalent of 32,000 metric tons of CO₂ annually, which is equal to 18% of AUO's reported SF₆ 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.
- **Process Changes and Enhancements:** In 2017, the Green Production Team under the Green Manufacturing Subcommittee implemented 523 projects including installing energy-saving chillers/pumps, introducing wireless smart meters and (specific to reducing F-GHGs) enhancing the efficiency of the PFC abatement systems. 45% of the emissions reduction was achieved through refined procedures and enhanced management, whereas 55% was achieved through investments.

Alternative Chemicals

- **NF₃ Substitution:** AUO uses NF₃ instead of SF₆ in cleaning, since NF₃ has a lower global warming potential (GWP) and it is used more efficiently.
- **Ongoing Research:** AUO continues to research the possibilities of using alternative gases with lower or no GWP in conjunction with optimizing process efficiencies and implementing abatement systems.

Gas Recycling/Reuse

- **Recycling Test:** In 2012, AUO tested gas recycling technologies and recycling efficiency at one fab.
- **Reuse Pilot:** In 2013, AUO's Longtan site introduced a membrane separation method that purifies SF₆ so that it can be re-used in the manufacturing process. However, due to a higher maintenance demand and lower efficiency, the recycling system has been replaced by an abatement system.

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).

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 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 to 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.

- By setting 2005 as the base year, AUO expects to achieve a 20% GHG reduction by the end of 2030 with an additional 30% reduction before 2050 to cut emission levels in half that compared to 2005.

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 SF₆ 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.

VERIFICATION STATEMENT OF GREENHOUSE GAS ASSERTIONS

Statement No.:
00012-2018-09-1001

Issue2 date:
27 April 2018

Page 1 of 3

This is to verify Initial reporting of Greenhouse Gas Inventory Management Report (2017) 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 (2017) (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 Report of March 13, 2018 is free 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.

Chen-Jian Lin
GHC Center



Place and date:
Taipei, 27 April, 2018

For the Issuing office:
DNV GL Business Assurance Co., Ltd.
2001, No. 29J, Sec 2, Xinyuan Rd.,
Banqiao District, New Taipei City 220,
Taiwan



Management Representative

Lack of fulfillment of conditions as set out in the Certification Agreement may render the Certificate invalid. This Verification Statement is based on the information as provided by the client and is not intended to assure the engagement conditions set out above. Hence, DNV GL cannot guarantee the accuracy or correctness of the information. DNV GL cannot be held liable for any party relying or acting upon this Verification Statement.
DNV GL Business Assurance Co., Ltd. | 100020 | 29-J | 2001 | TEL: +886 2 62571998 | website: www.dnvgl.com/tai

Sources

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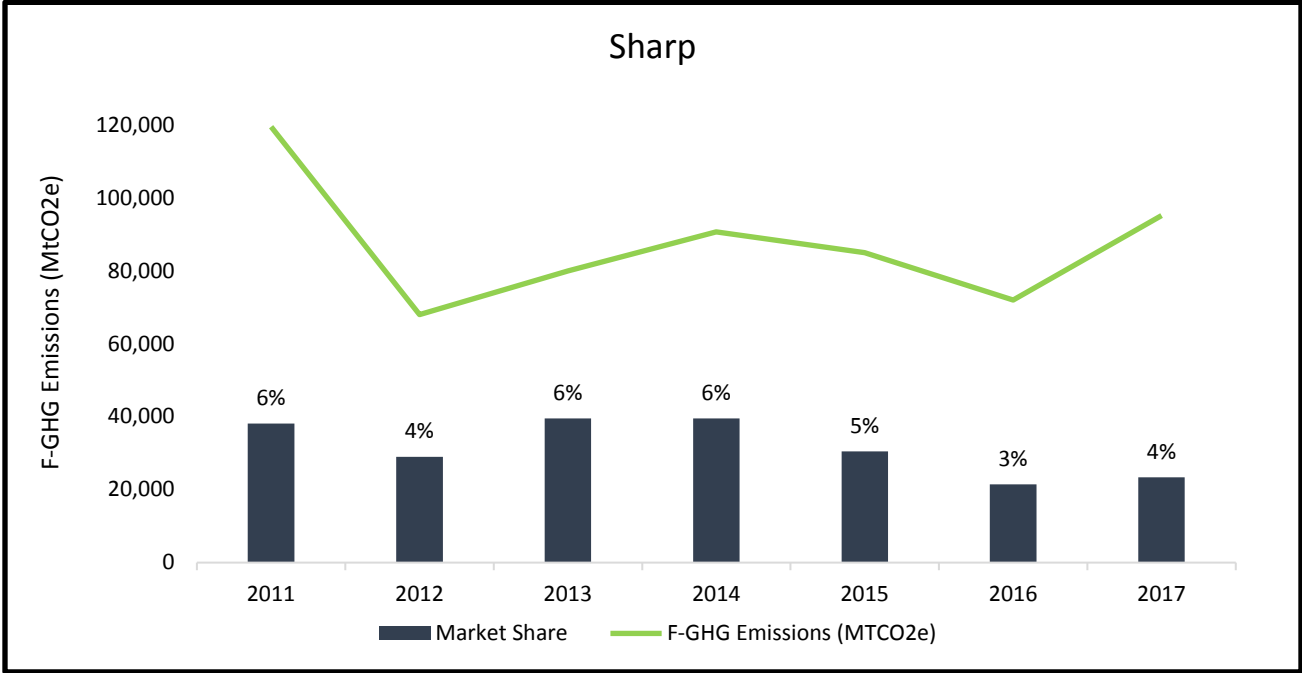
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Sharp 2017 Data

4% 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-GHG 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 2017, Sharp emitted a total of approximately 95,125 metric tons of CO₂ equivalent (MtCO₂e) of F-GHGs, as follows:¹⁰
 - HFCs: 2,465 MtCO₂e
 - PFCs: 44,654 MtCO₂e
 - SF₆: 38,204 MtCO₂e
 - NF₃: 9,802 MtCO₂e

Gases Targeted

- SF₆
- PFCs (CF₄, C₂F₆, C₄F₈)
- HFCs (CHF₃)
- NF₃

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.

Gas Recycling/Reuse

Not applicable.

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.

¹⁰ Sharp reports annual emissions for its fiscal year, April 1 through March 31, rather than calendar year.

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 CO₂e/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 2017, the Sharp Group's GHG emissions decreased by 6.4% compared to the previous fiscal year Participation in Broader F-GHG Reduction Efforts

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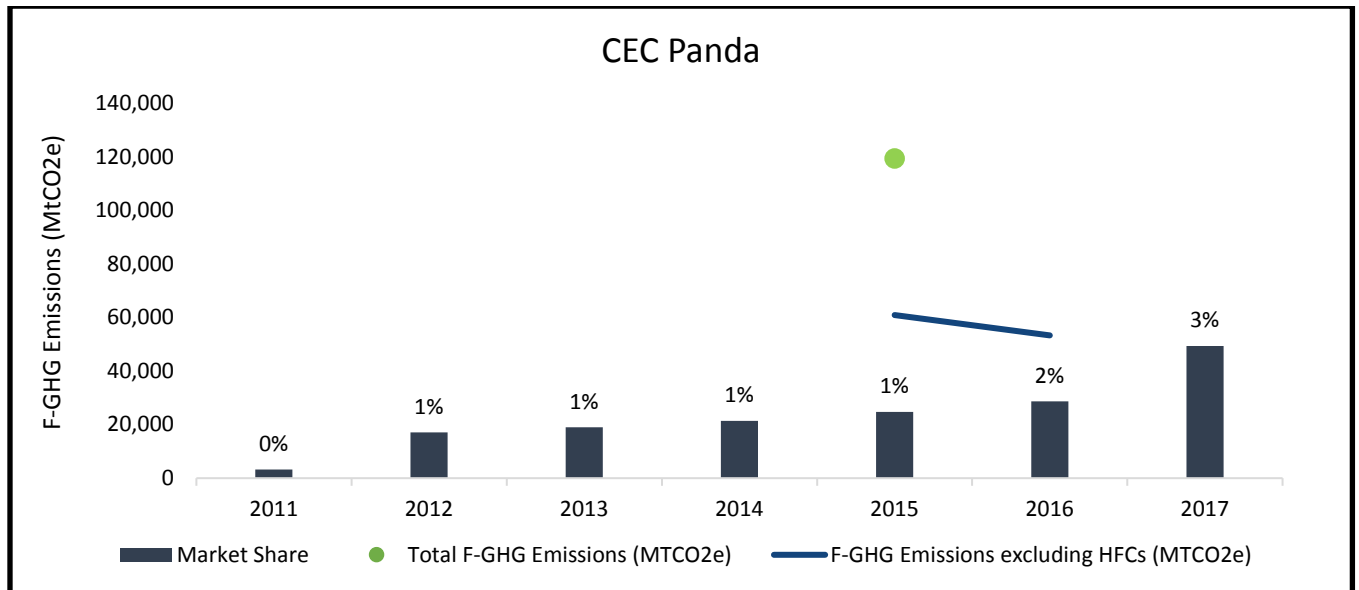
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CEC Panda 2017 Data

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-GHG emissions 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 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 CO₂ equivalent (MtCO₂e) of F-GHGs, as follows:¹¹
 - PFCs: 2,297 MtCO₂e
 - SF₆: 11,082 MtCO₂e
 - NF₃: 39,933 MtCO₂e

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.
- In 2016, CEC Panda implemented 37 projects to reduce GHG emissions by an estimated annual 7301 CO₂e savings in metric tons CO₂e.

Participation in Broader F-GHG Reduction Efforts

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

Sources

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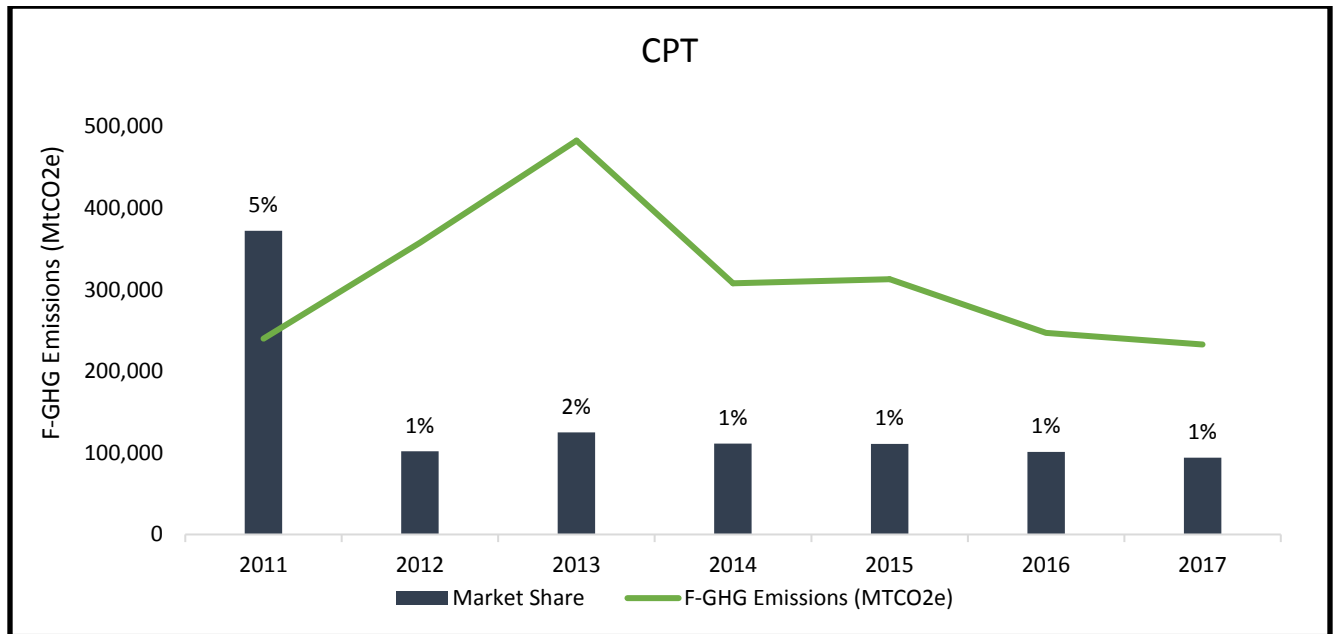
CEC PANDA's responses to the 2017 CDP Investor Questionnaire

¹¹ CEC Panda reported HFC emissions in 2015 but not 2016 or 2017.

Chunghwa Picture Tubes (CPT) 2017 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-GHG 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

- In 2017, PFC emissions accounted for 30.27% of CPTs GHG emissions which were 769,615 MtCO₂e. Based on this information, CPTs PFC emissions for 2017 were estimated to be 232,962 MtCO₂e, a 5% decrease since 2016.

- In 2016, CPT emitted approximately 247,112 metric tons of CO₂ equivalent (MtCO₂e) of F-GHGs, a 55% reduction from 2008, compared to a 49% reduction from 2008 in 2015 (313,000 MtCO₂e).
- Between 2002 and 2017, CPT reduced F-GHG emissions by approximately 36.15 million MtCO₂e. This is equivalent to removing 7.7 million vehicles from the road for one year.

Gases Targeted

- SF₆
- PFCs
- HFCs
- NF₃

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 MtCO₂e.

Alternative Chemicals

- **SF₆ Replacement:** CPT is using lower GWP gases, where possible. For example, CPT continues to implement carbon reduction activities by replacing SF₆ with NF₃ 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 MtCO₂e 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 ton CO₂, which represents a decrease by around 411,000 tons CO₂ or 34.82% compared to 2008.

- In 2016, CPT's GHG emissions were 778,618 MtCO₂e, an increase from 778, 618 MtCO₂e 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.

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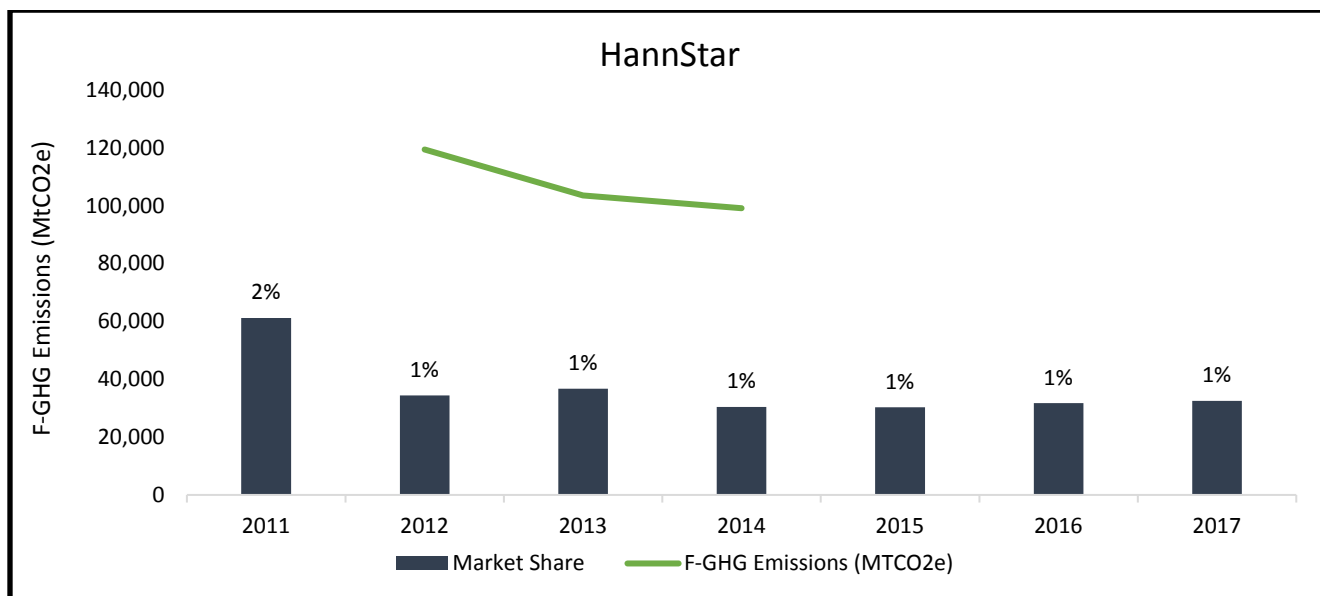
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HannStar 2017 Data

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

- In 2017, HannStar reduced approximately 29,100 metric tons of CO₂ equivalent (MtCO₂e) of F-GHG emissions.

Emissions Intensity:

- HannStar's total GHG emission intensity increased from 0.072 MtCO₂e/m² to 0.075 MtCO₂e/m² from flat panel manufacturing processes of panel produced in 2016 and 2017.

Gases Targeted

- SF₆
- NF₃
- Other PFCs

Processes Targeted

- Etching
- Cleaning

Approaches Used

Abatement

- **Local Scrubber:** HannStar has installed a high efficiency local scrubber to reduce emissions of SF₆, NF₃ and other PFCs.
- **Abatement Systems:** HannStar will install abatement systems in all newer generation fabrication facilities (fabs).

Process Improvements

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

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.
- HannStar's plants in China have been developing GHG inventories since 2012, but have not had these inventories verified by a third party.

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.

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HannStar 2017 Corporate Sustainability Report (page 27). Available at <http://www.hannstar.com/Common.aspx?mid=259&tmid=6&modid=1>

Suppliers Without Public Data in 2017

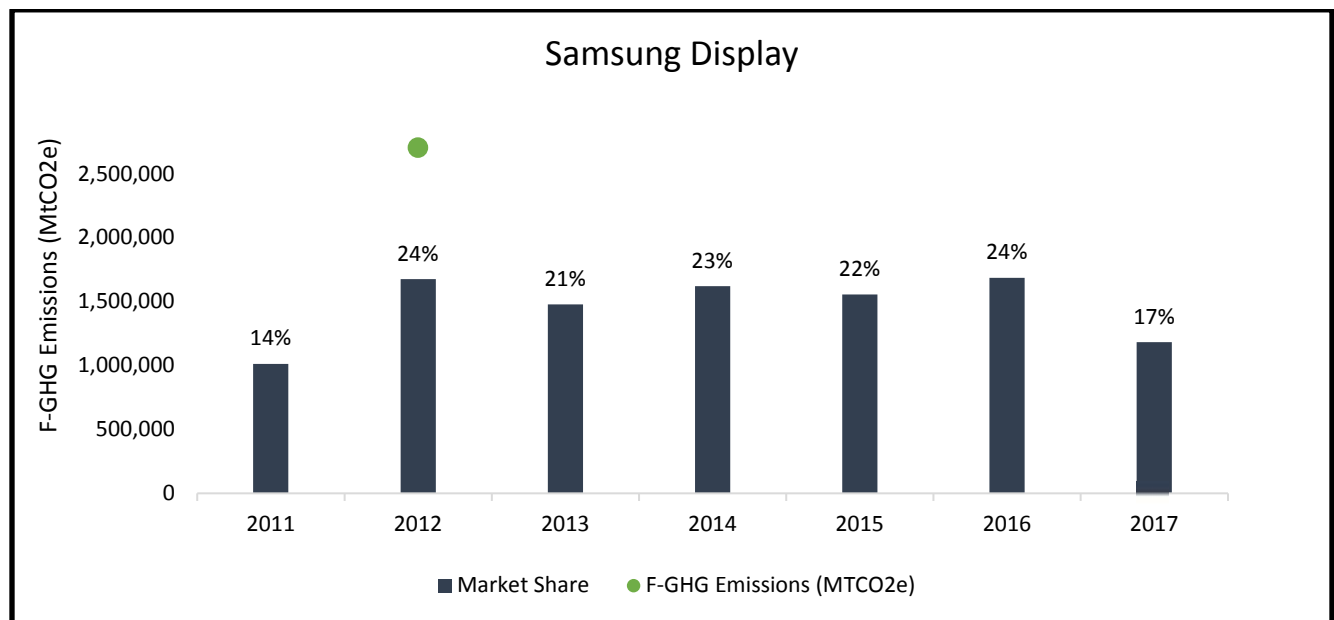
Samsung BOE China Star, and Infovision did not report public data in 2017. As a result:

- 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 2017 market share:

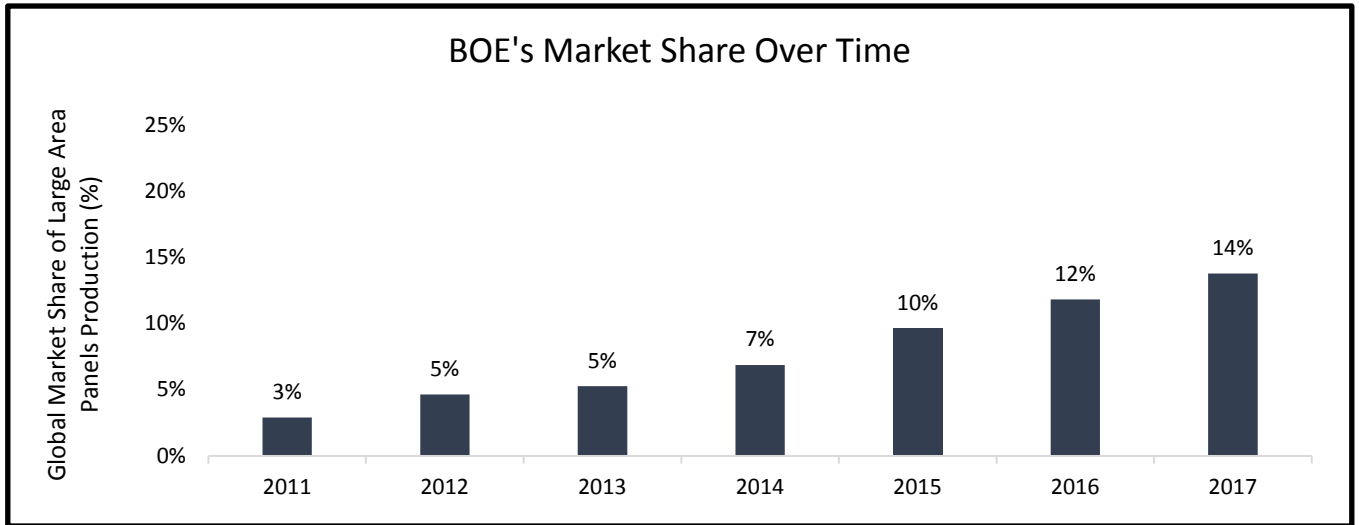
Samsung Display

17% Market Share in 2017



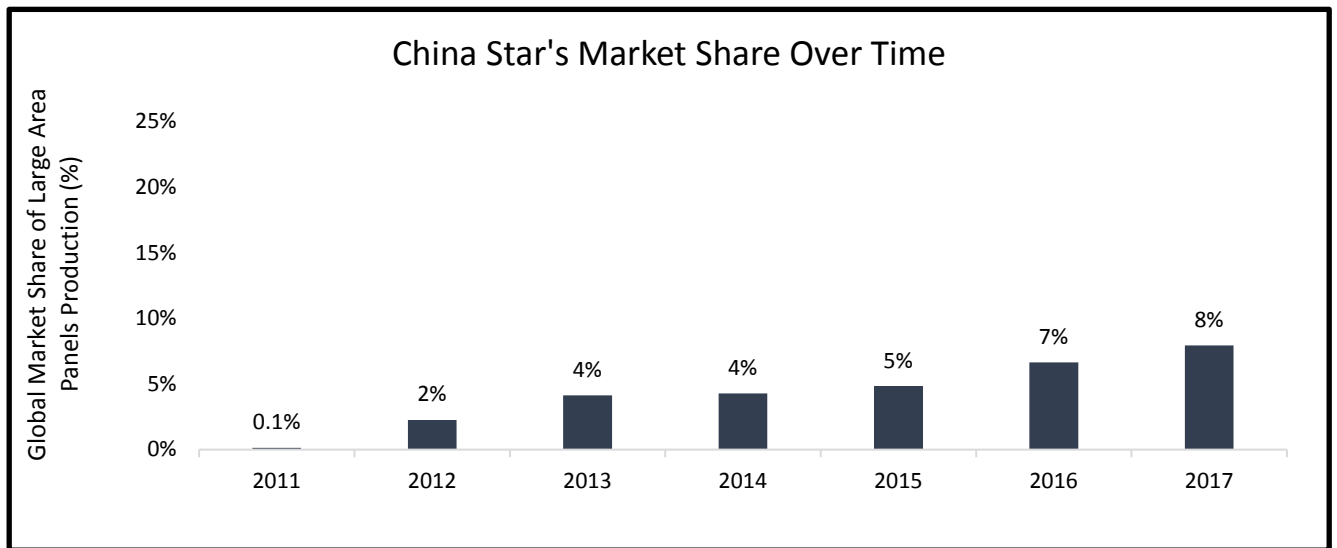
BOE

14% Market Share in 2017



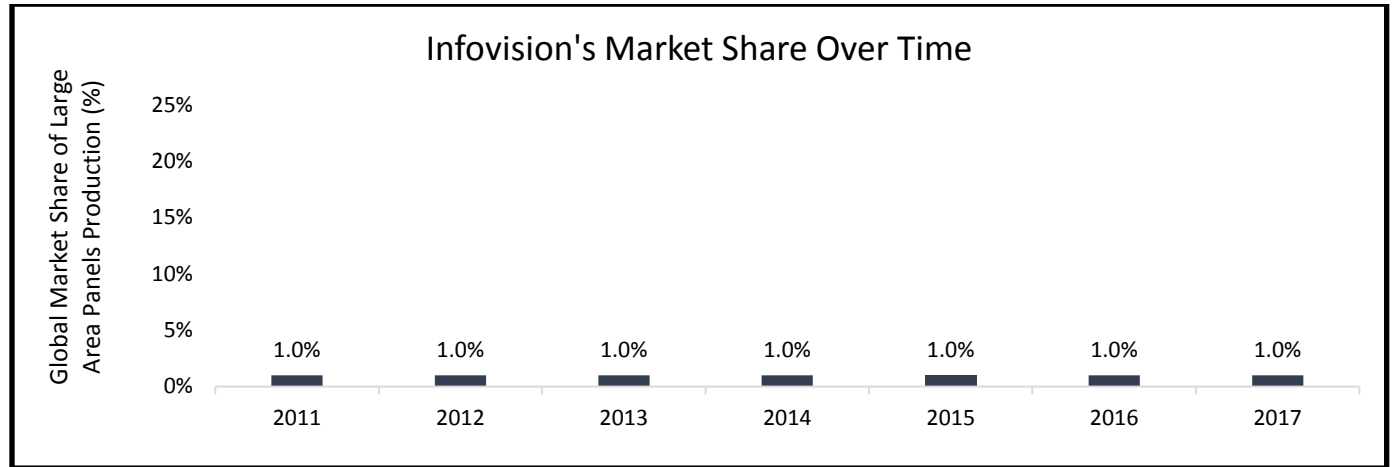
China Star

8% Market Share in 2017



Infovision

1% Market Share in 2017



Sources

Republic of Korea: An Emissions Trading Case Study. Available at

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