

NEXT GENERATION TV PANEL TECHNOLOGY AND MARKET TRENDS 2020

Market & Technology Report - July 2020

China has won the LCD war. Now, LG, Samsung and others are readying complex and expensive technology investments to fight the battle for the next generation of TVs.

WHAT'S NEW

- Fully updated TV panel forecast and supply/demand analysis
- Detailed analysis of TV panel maker status and strategies
- Detailed analysis of miniLED backlights
- Analysis of Samsung's QNED technology

KEY FEATURES

- TV panel forecast by size, technology
- TV panel capacity forecast by region, panel maker, fab generation and technology
- Panel maker profile and strategy
- Analysis and forecast of emerging TV features: large sizes, 8K, high dynamic range, wide color gamut
- Analysis and forecast of current and future TV technologies: enhanced LCD including QD films, phosphors, miniLED and dual cells, OLED, including WOLED, RGG inkjet-printed OLED and QD-OLED and emerging self-emissive technologies, including microLED and QNED and electroluminescent QD

REPORT OBJECTIVES

- Provide a detailed analysis of the status of the TV Panel industry: capacity, volume forecasts, supply vs. demand analysis, strategy of key players, Covid-19 impact etc.
- Analyze present and future TV panel technologies including: LCD plus quantum dot color filters (QDCF), miniLED, Dual Cell, WOLED, RGB OLED inkjet, microLED, QNED, EL-QD.
- Analyze the key features of next-generation TVs including 8K, high dynamic range and wide color gamut, understand which technologies are best-positioned to deliver them, and explore the intersections to understand the impact on leading panel makers and their strategies.

CHINA WON THE LCD WAR. NOW 2020 WILL BE A TRANSITION YEAR

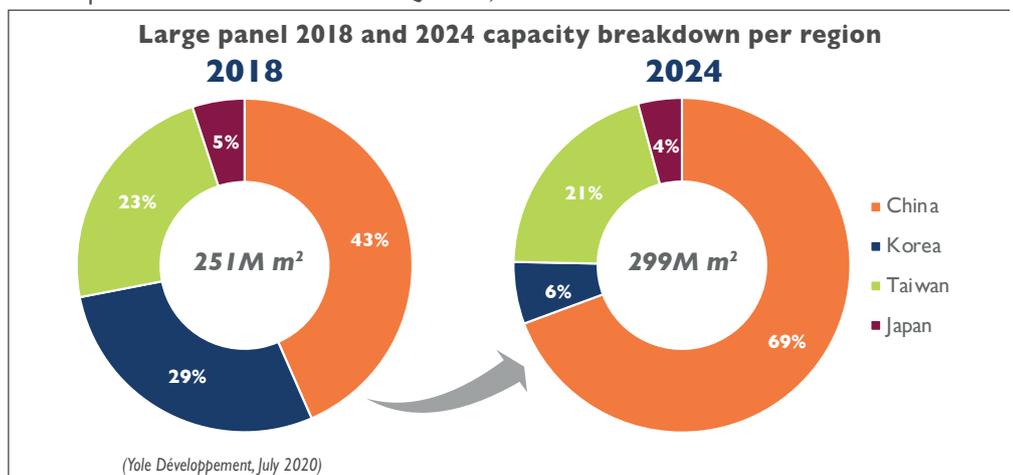
Driven by the Chinese central government's five-year plan directives, the country's display panel industry replicated a strategy already successfully used by domestic companies to gain supremacy in other industries such as photovoltaic panels, sapphire substrates or LED chip manufacturing.

The TV panel market was disrupted by the rise in China of large players that have increased capacity regardless of demand. In 2019, oversupply sent prices to their lowest levels ever, below cash cost for most players. Thanks to subsidies, lower depreciation, and newer and more efficient fabs, BOE and CSOT can control prices to eliminate competition. Korean and Taiwanese LCD panel makers turned unprofitable and it became clear that China would soon close the technology gap, leaving no opportunity for differentiation, and then control prices and own the market. In Q1-2020,

Samsung and LG therefore decided to almost fully retreat from the LCD TV panel business.

In the meantime, the Covid-19 pandemic impacted the supply chain and demand in the first half of the year.

Until late 2019, the industry had severe and lasting excess capacity. The tables have now turned. Samsung and LG will remove the capacity to produce more than 52 million m² of large panels by 2021, accounting for 18% of 2019 global capacity. Meanwhile, Chinese players are adding 42M m² worth of capacity. There are now risks of shortages from 2021 and beyond. This could be exacerbated if Taiwan makers shut down their least efficient fabs and if China converts some LCD lines to OLED rather than proceed with greenfield investments, as conversion typically cuts fab capacity by 50 to 66%.

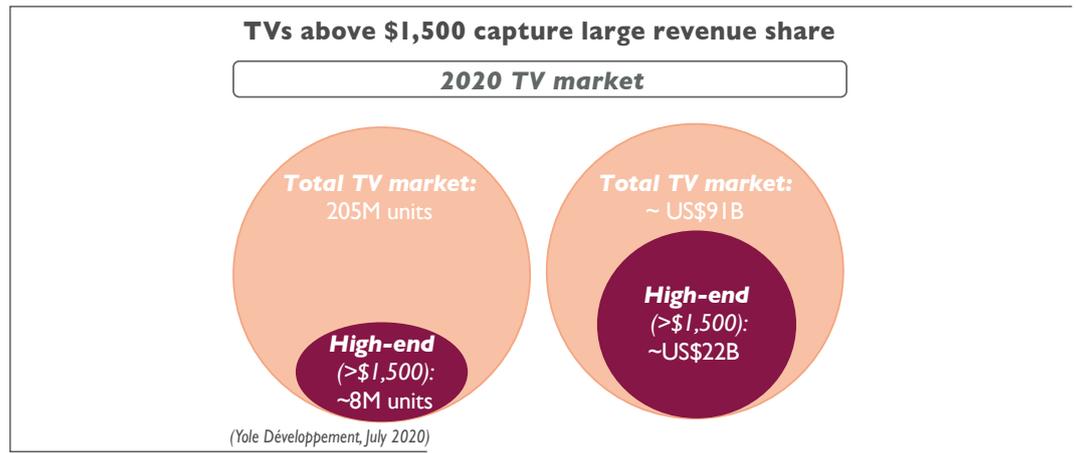


REVENUE AND MARGINS LIE IN SELF EMISSIVE TECHNOLOGIES, BUT LCD IS HERE TO STAY

OLED was once thought to be the sure winner in the high-end TV market, but LCD is increasingly efficient at competing in this segment as well. Technologies such as quantum dot (QD) films, Full Array Local Dimming and miniLEDs significantly improve LCD performance while leveraging the existing LCD manufacturing infrastructure and requiring little to no additional capital expenditure (capex). The performance gap between LCD and OLED shrank while white OLED (WOLED) failed to reduce the cost gap. As a result, OLED is facing increased competition from LCD in the high-end segments, forcing LG to reduce WOLED panel prices for the first time in years. LCD will hold 98.2% of the TV market

in 2020 and remain unchallenged on entry-level and mid-range segments. It will still capture 94% of volume in 2026 although its revenue share could drop below 75%.

To support margins and revenue, the industry is attempting to compel consumers to upgrade their TVs to more expensive models. Wide Color Gamut (WCG) and High Dynamic Range (HDR) are now standard on high end TVs and are propagating into mid-range products. For 8K, however, despite a nascent ecosystem, adoption is still hindered by high cost and price, lack of native content and multi-level bottlenecks through content generations and delivery.



DIFFICULT TECHNOLOGY CHOICES FOR PANEL MAKERS

Options for the next generation of TV panel technologies keep proliferating. To win the next battle, risky, multi-billion dollar bets need to be made now. Those choices will decide the fate of Korean panel makers. LG Display got a head start with WOLED. Its new Guangzhou G8.5 fab scheduled for late 2019 was delayed by Covid-19 and yield issues. With WOLED sales below expectation in 2019 and 2020, LG postponed ramp up until late July for fear that depreciation would further harm its financials if it can't quickly fill its capacity. A G10.5 WOLED fab investment was also put on hold indefinitely. In the short term, LG must improve manufacturing efficiency through yields and multi-model glass in order to lower costs, and stimulate demand.

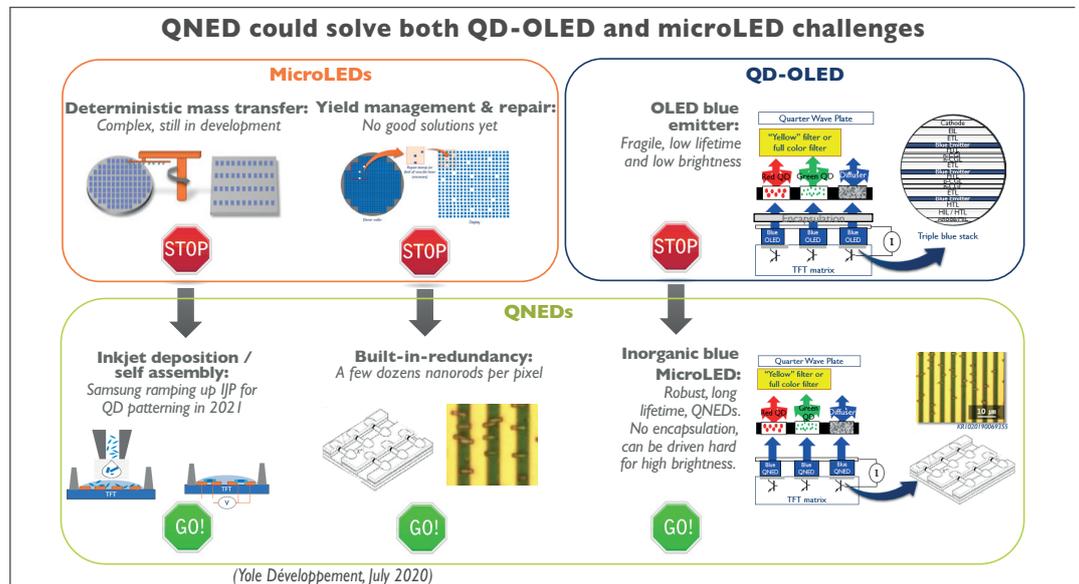
Samsung is pursuing a dual track strategy. Its panel division Samsung Display (SDC) is investing \$11B including \$8.4B of capex to build a Gen 8.5 QD-OLED fab. Its Visual Display TV set division prefers milking its profitable QLED LCD brand, and upgrading it with miniLEDs in 2021 while developing microLEDs. After retreating from LCD, SDC will depend on its mobile OLED business for revenue. It therefore needs QD-OLED ASAP to remain in the TV business. Its Quantum Nano Emitting Diode (QNED) technology could fast track microLEDs if development succeeds.

WOLED and QD-OLED are stop-gap technologies. BOE and CSOT are both eager to skip WOLED

and level the playing field by jumping directly to the next generation, either inkjet-printed red/green/blue (RGB) OLED or electroluminescent (EL)-QD. CSOT's \$187M investment in JOLED gives more credence to its plans to build G6 and G8.5 RGB OLED fabs by 2023. If successful, this could render QD-OLED and WOLED fabs mostly obsolete. Samsung and LG must therefore proceed with caution on their QD-OLED and WOLED investments while accelerating their own RGB OLED and EL-QD development.

AUO, Innolux and Sakai Display strongly benefit in the short-term from Samsung and LG's exit from LCD. The need of some TV brands to maintain reliable panel sources outside of China to mitigate supply chain risks could reduce long term risk. However, they have not significantly invested in OLED. In the longer term, microLEDs could be AUO's and possibly Innolux's best shot at offering high-end, large TV panels without the massive capex of an OLED fab.

MicroLED's unique ability for bezel-less tiling could enable the manufacturing of displays of arbitrarily large size. All leading panel makers are accelerating their development. Luxury microLEDs TVs priced above \$50,000 will enter the market in 2021 but microLED cost, yield and manufacturability roadblocks are hard to lift. For the consumer market, microLED remains an outsider for the time being.



(Yole Développement, July 2020)

COMPANIES CITED IN THE REPORT (non exhaustive list)

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6.4 The Buyer shall be solely responsible towards the Seller for any infringement of the obligation described in Article 6.3 above, whether such infringement originates from the Buyer’s employees or any person to whom the Buyer has sent the Products. Furthermore, the Buyer shall initiate and personally take care of any related proceedings in coordination with the Seller, and the Buyer shall bear the related financial consequences in their entirety.

6.5 The Buyer shall define within its Company an identified user who shall serve as a contact person for the License purchased by the Buyer. This person will be the recipient of each new report. This person shall also be responsible on behalf of the Buyer, for compliance with all copyrights and other obligations relating to the protection of the Seller’s IP rights and general compliance with the terms of the License purchased by the Company. In the context of Bundle and Annual Subscriptions, the contact person shall decide within the Buyer which person(s) shall be entitled to receive the protected link that will allow the Buyer to access the Products.

6.6 It is acknowledged and accepted by the Buyer that whether purchased in the form of Bundles or Annual Subscription, all unselected reports will be deemed cancelled and lost after a period of 12 month following acceptance of the corresponding order by the Seller in accordance with provisions of Article 1.3 above .

6.7 It is further acknowledged and agreed by the Buyer that any investor in the Buyer Company, any external consultant of the Buyer Company or any joint venture done with a third party in which the Buyer Company is involved , is not entitled to use a Product, without paying to the Seller the full price for a license to the required Product..

7. TERMINATION

If the Buyer cancels the order in whole or in part or postpones the date of mailing, the Buyer shall indemnify the Seller for the entire costs that have been incurred as at the date of notification by the Buyer of such delay or cancellation. This may also apply for any other direct or indirect consequential loss that may be incurred by the Seller, pursuant to such cancellation or postponement.

8. MISCELLANEOUS

8.1 All the provisions of these General Terms and Conditions of Sale are for the benefit of the Seller, but also for that of its licensors, resellers and agents. Each of them is entitled to assert and enforce these provisions against the Buyer.

Any notices under these Terms and Conditions shall be given in writing and shall be effective upon receipt by the other Party.

8.2 The Seller may, from time to time, update these General Terms and Conditions of Sale, and the Buyer, shall be deemed to have accepted the latest version of such General Terms and Conditions of Sale, once they have been duly communicated to the Buyer by the Seller.

9. GOVERNING LAW AND JURISDICTION

9.1 Any dispute arising out or linked to these General Terms and Conditions of Sale or to any Licenses or Products purchased in application thereof shall be submitted to the French Commercial Court of Lyon, which shall have exclusive jurisdiction upon such issues.

9.2 French law (without reference to any applicable conflict of law provisions) shall apply to these General Terms and Conditions of sale and any agreement between the Buyer and the Seller made pursuant thereto.