

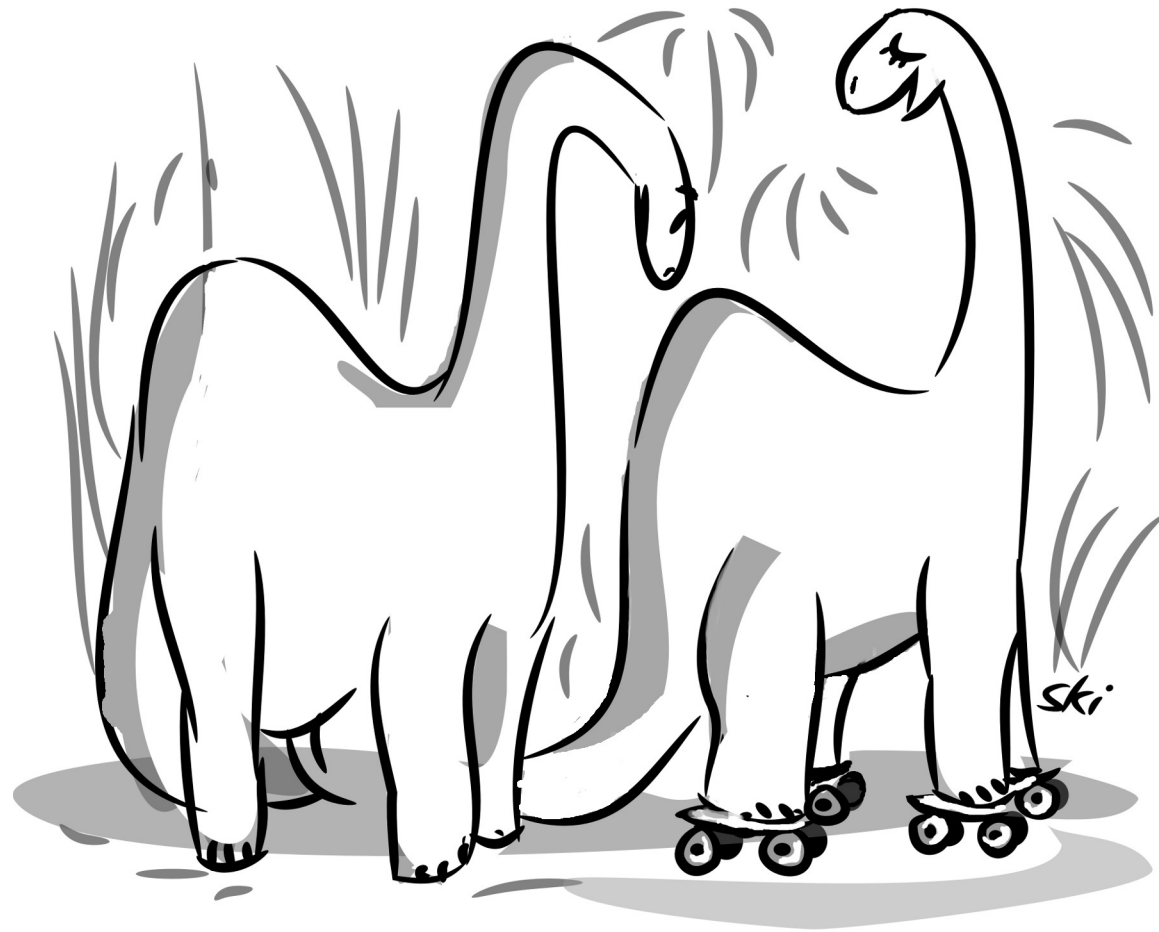


Innovate or die

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Innovate or die
The new display
industry mantra
in response
to the Gen 10s



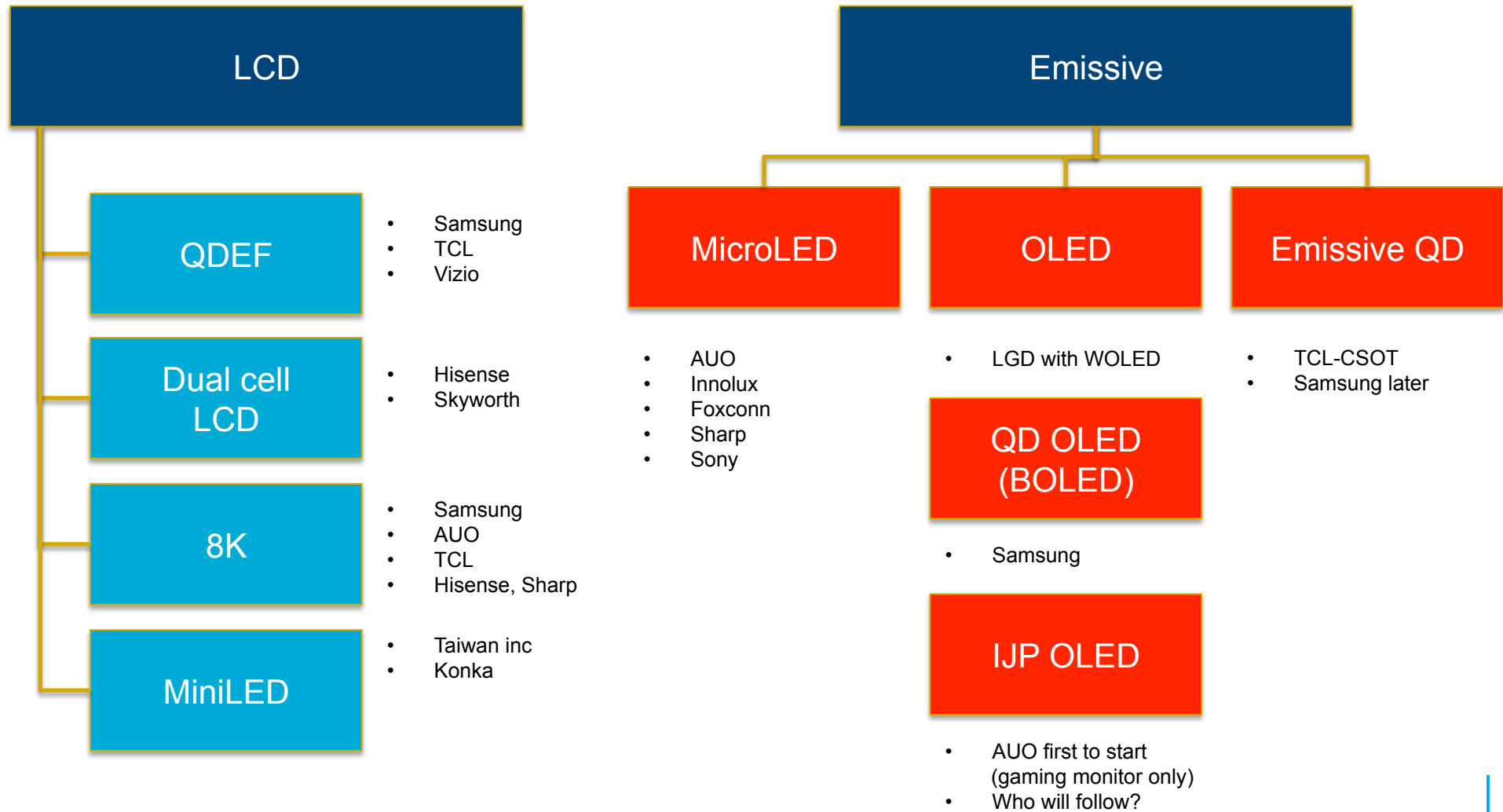
Innovate or die.

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Context: Market pricing falling but display players innovating on steroids to try to create new premium options for TV

- Gen 10 fabs are now ramping up: BOE further ramping its first Gen 10 and CSOT beginning to ramp up T6; additional Gen 10s expected in coming years
- Large panel players seems to recognise the threat and seem to be throwing everything they have into new technology innovations to try to change the game. We count 8-9 new technologies that are being pushed out into the market at the same time
- The aim of this presentation is to try to separate these into the important ones and the gimmicks and to try to outline the factors which would lead to each being more or less important
- Case examples do show that multi-technologies can survive alongside each other for a period of time, and that if one wins, it is often LCD
 - How should we view this market and what does this mean for the future?
- This is a very rich topic and we present our first thoughts here – we look forward to your feedback also. We may well issue other market briefings on this topic as it is a rich one of technology marketing

Unprecedented technology innovations to try to create the new premium all at the same time with key display cos and brands all for the TV space



This multi-technology push unheard of for quite a while: Case examples

TV push in early 2000s

- Back in the early 2000s, a-Si LCD was up against a cast of characters from FEDs, SEDs, PDP, PALC and other new large panel technologies
- In the end the sheer scale of the LCD industry and the number of engineers working on LCD issues led a-Si to being the winner
- The lesson here is probably never to underestimate the incumbent technology

Multi-display in telecom in early 2000s

- In the early 2000s there was a head on battle between CSTN, transmissive a-Si, transfective a-Si and some LTPS with some PMOLED also for smartphone/ candy bar phone displays
- Biggest head on battle was transfective (lead by Nokia) against technology push by the Koreans of transmissive a-Si
- Transmissive a-Si could probably have been said to be the overall winner, and eventually transfective fell out of favour

The question is which factors determine which technologies win:

1: Price points

- Many consumers do not understand the technology differences, but price points matter

2: Supply

- The ability and volume that the industry can supply behind any specific technology is important

3: Leadership moves

- What LGD and SDC do matters: industry is looking to them for leadership
- “You go first” also a mentality in taking new risk

4: Brand support

- Looking at how many TV brands adopt the technology matters
- Commercial links as important as technology development

5: Capital intensity and component cost

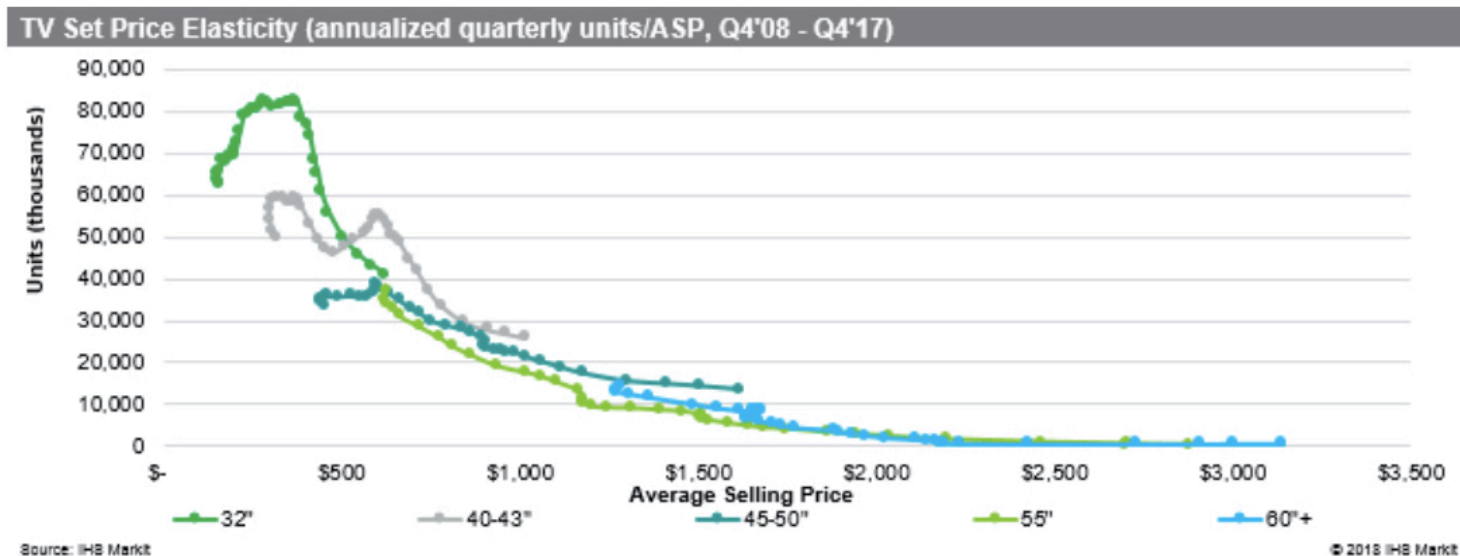
- We have always believed that those innovations that can be delivered without major capital expense probably have a greater chance of upside than those based on building fabs

6: Technology Maturity

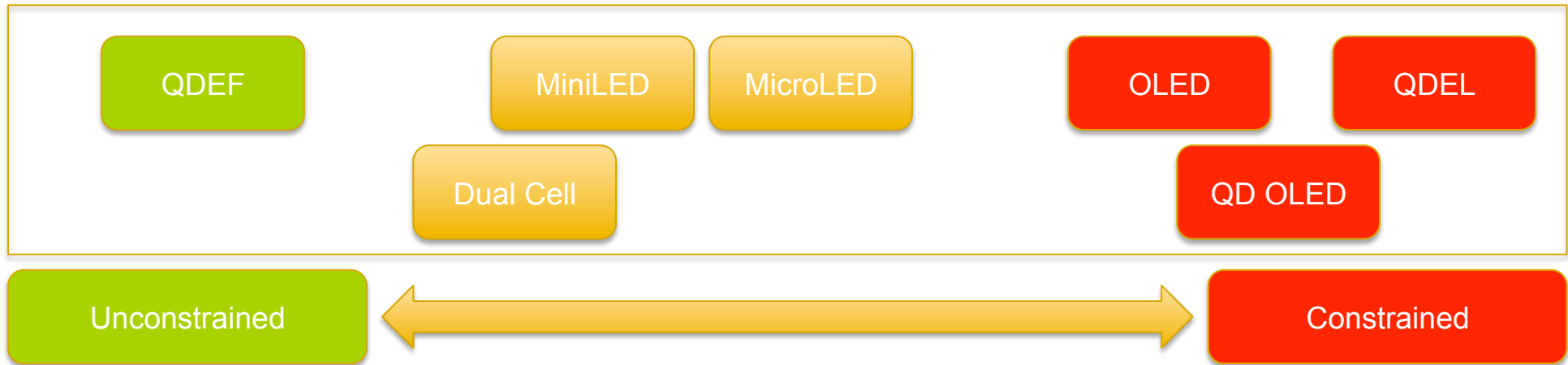
- Of the 8-9 technologies we show in this presentation it is clear that they are at different levels of technical maturity

1: Price point matters

- Overall we think that price points matter: all technologies can be cleared through the market – it is just a matter of price
- Samsung in 2017-2018 overpriced their QDEF offerings leading to market share loss
 - In the same period LGE made share gains with WOLED
- While brands want to get a premium for their offerings, consumer TVs are very price sensitive
- We see signs that QDEF sets are being priced at lower numbers as positive and will aid in overall adoption



2: Supply matters



- As from the case example of smartphone displays in the 2000s, the eventual winner (transmissive a-Si) was largely due to the fact that LGD and SDI (at the time) could push through fairly high quantities of product could be pushed out onto the market at lower cost
- Three of the technologies above rely on specific fabs to be built or converted: OLED, emissive QD and QD-OLED
- The QDEF market by comparison (which is a drop in QDEF film into the BLU tray of an LCD) is relatively supply unconstrained by now (multiple film suppliers all willing to supply film)
- MicroLED and MiniLED are both constrained for now by technology issues and cost economics: the transfer costs and LED costs make both too expensive: miniLED by a little, MicroLED by a lot

3: Leadership moves matter

Top tier leaders in driving new technologies

SDC

LGD

BOE

CSOT

- Overall the display industry often shows herd like adoption behaviours – one leading player moves and the rest follow
- For now in the area of premium TV offerings, then SDC and LGD are the most important leaders
 - SDC has the proven capability to create complete ecosystems to support its products
 - LGD for now has the high ground, having spent billions to move forward large panel WOLED and finally move this to profitability
- If we had to add one more player to this list it might be BOE. BOE for now has pursued a pretty eclectic and technology agnostic approach (We do everything) but more and more we imagine that players in China will be influenced by the direction it chooses to take
 - Number 2 in China would be CSOT

4: Brand support

OLED camp



QLED camp

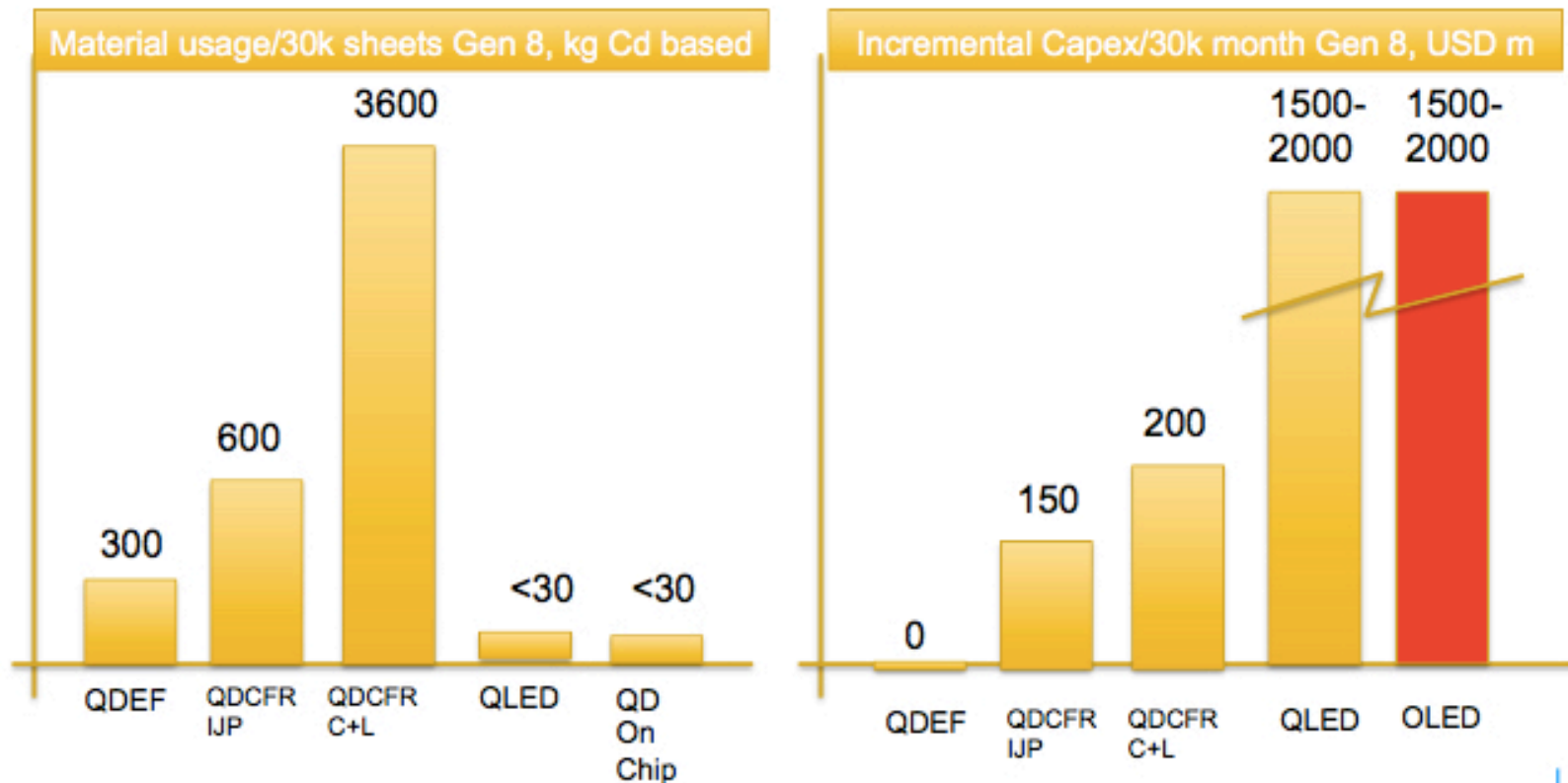


SAMSUNG



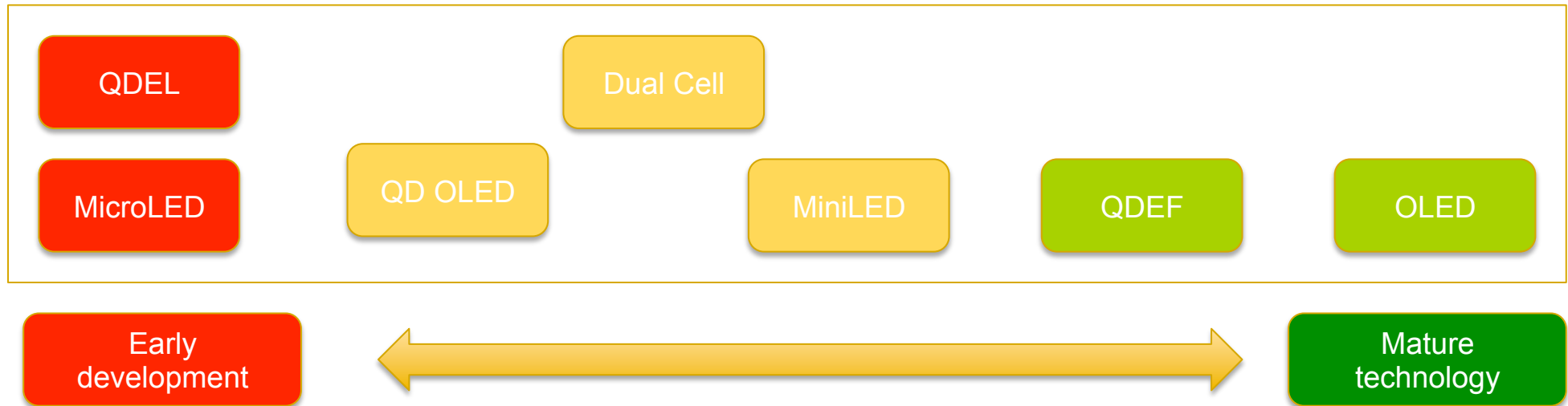
- This was a slide I presented last September looking at the key players in the “OLED vs QLED” camps. Hisense has also offered WOLED under a different brand
- At the time (and even now) OLED seems to be broader brand support: this is Samsung’s key challenge in making QD variants more successful

5: Capital intensity and component costs matter (example shown)



- QDCFR now no longer a serious technology contender due to difficulty of in-cell polariser
- One of the reasons we saw QDEF as an key technology was given the low capital requirements
- QLED here means emissive QD (QDEL)
- QD OLED here may well have similar usage patterns as the QDCFR case and investment level in line with the QLED case
- For the MiniLED and QDEF technologies, as examples, the component cost matters

6: Technology maturity



- For now QDEL and MicroLED remain at very early stages in development: QDEL is mostly material lifetime constrained (especially for non-Cd QDs) but both Nanophotonica and Nanosys are working hard on appropriate non-Cd dots for QDEL and TCL may have shown some interest in trialing QDEL in China with Cd-based QDs
 - MicroLED currently constrained by quality-binning and cost issues mostly due to transfer costs and yields
- QD OLED has a large number of technical challenges to face for Samsung before it can move to being a more viable technology (not in the least that Samsung is less experienced with oxide than LGD)
- Dual cell is simple to implement but needs volume – so far only Hisense supporting it as a brand
- OLED and QDEF could now arguably be called mature technologies

So what does that mean for our 8-9 technologies:

Technology	Price	Supply	Tech maturity	Brand support	Cost/Capital intensity	Summary
QDEF	Low	Film based technology	Mature technology	Samsung, Vizio, TCL, Hisense	Low component cost (\$20/m2)	Mature technology being adopted
Dual cell	Low-Mid	Massive supply base	Fairly straightforward	Hisense	Low component cost (<\$50/m2?)	Feels like a gimmick but might be interesting
8K (LCD)	High	Massive supply base	Yield dependent	Samsung, Sony, Sharp Others	8K means lower yields and some higher DIC cost	Technology push and perhaps a tad early
MiniLED LCD	Low-Mid	Depends on component cost	Development	Foxconn and others	Foxconn/DSCC says <\$100 here	All depends on the cost: local dimming approach
MicroLED	Very high	Many technical issues	Early development	Samsung Sony	Cost currently very very high	Technology still very immature with yield binning and other issues
OLED	High	Limited to LGD fabs	Mature technology	Many (see earlier)	Capital intense: Technology specific fab	Mature technology brought to market by LGD/LGE
QD OLED	High+	Limited to new Samsung fab	Development	Samsung	Capital intense: Technology Specific fab	Samsung's version of WOLED
OLED IJP RGB	High-	Future technology	Proven waiting on equipment	Product not available yet	Capital intense: Technology specific fab	AUO has taken the plunge. Equipment being developed for Gen 8-10
Emissive QD (QDEL)	High++	Future technology	Very early development	Product not available yet	Capital intense: technology specific fab	Technology still many years out

Technology by technology: What might happen and how can each improve its position?

QDEF and QDOG

- Technology is a drop in QDEF film into the BLU tray of an LCD
- Current film prices are low and beginning to compete with KSF phosphors (<\$20/m²)
- Technology adoption may depend on brand support and film/set pricing
- Film is broadly available from a number of suppliers

Dual cell

- This feels like a gimmick but does deliver very high contrast
- A monochrome LCD cell behind the main RGB cell achieves the same as a high number of local dimming zones
- Recently put forward by Hisense in China as an idea for a premium offering

8K

- IHS believe that the emergence of 8K may be too early for adoption due to where we are in the adoption for 4K
- The economics of broadcast or streaming with this much visual information are not yet clear
- Selling pixels has always worked for the display industry so not surprising to see Samsung, AUO and others pile on

MiniLED

- The use of Mini LEDs to form local dimming approach with high number of local zones
- Cost is the key factor here in adoption and most miniLED backlights up to now have been too expensive
- Recent Foxconn news that this may be less than \$100 BLU cost based on very inexpensive dies – this may begin to get some traction

Technology by technology: What might happen and how can each improve its position?

OLED

- Already a mature technology
- Took LGD many years to get this to decent volume and profitability (>5 yrs)
- WOLED + CF approach the current leading approach
- Printing now offers to move this to the next level. AUO have committed and others may take the plunge. Materials and equipment at Gen 8-10 getting there soon

QD OLED

- Samsung's variant on the WOLED approach from LGD is based on a blue OLED stack with QD CCL layers (and a colour filter)
- For now this technology has quite a number of technical challenges on top of mastery of the oxide backplane
- For now this could be a more expensive technology even than WOLED

Emissive QD

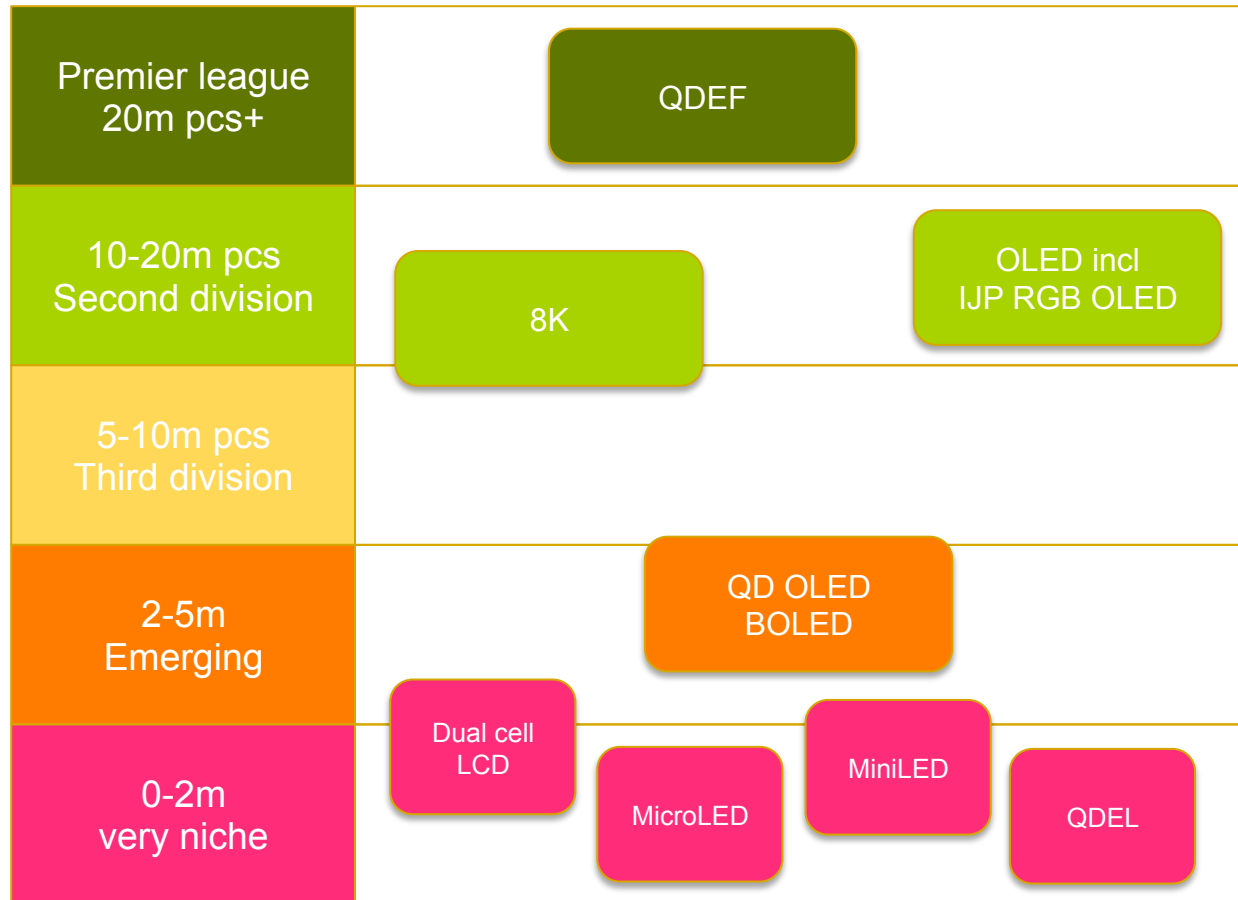
- Emissive QD technologies are really only being talked about at this stage
- For now constrained by lifetime of materials for Cd- and Cd-free QDs in electroluminescent mode alike. Cd-free probably tracking several years behind Cd-based
- TCL has made some noise about moving ahead with Cd-based QDEL in China for local consumption

MicroLED

- Samsung (SEC) pushing ahead for 75"+ MicroLED business at very high prices based on tiled approach
- Currently real LED binning problems

Our view (based on thoughts also from IHS) on the strength of each approach:

Potential number of pcs 2025 m, TV panels



- Based here on the IHS points of view (extrapolated in some cases) and our own thoughts
- Since it it demand unconstrained and already moving ahead the leader is QDEF in our view
- 8K value proposition may be challenging
- BOLED position assumes that Samsung moves fairly rapidly to build capacity once the technology is proven
- Both dual cell LCD and MiniLED could move upwards fairly easily based on the cost progression of the component and brand support

Overall it is the breakout leadership of the Korean's that really matters. Everyone is looking to LGD and Samsung to see what they choose to do

- For now it feels like we are in a power vacuum with the industry choosing to wait and see what the Korean's will do
- However, there is a chance that CSOT and BOE start to exert more leadership and TCL in particular (shareholder in CSOT) has shown great interest in QDEL
- Previous case examples have shown that LCD is a serious technology incumbent and tends to fight back
- While we do think some statements can be made about winners and losers there is still quite a bit that can change

Potential scenarios for industry development

Korea leads

- What SDC and LGD do matters
- OLED and BOLED/ QDEL become driving adoption
- IJP adoption

China leapfrog

- Perhaps a leapfrog ahead into QDEL models
- Decisions by CSOT and BOE critical

Free for all

- A technology free for all with many technologies flourishing in different supply chains

LCD wins

- There is a chance that LCD uses all of its box of tricks to move ahead and OLED-QDOLED are less important

Summary

- 2019 is almost unprecedented for the display industry (to my mind) in the level of technology innovation going on in a down (and highly competitive) market. Players seem to all be trying to change the game in an “Innovate or die” mode
- Picking winners is very difficult, but we have tried to demonstrate the role of a 6-factor model in looking for those likely to make it through
- For now at least there do seem to be a small cluster of “winners”: QDEF/QDOG and OLED (including IJP OLED) and there will be quite a number of new technologies that we still expect to be less than 2m units by 2025
- However, there is much that could change based on whether Korean or Chinese players seize the leaderboard and technology leadership
- We look forward to your thoughts and comments on this

Our services:

Growth strategy

- Market entry strategy
- Business unit strategy
- Growth strategies for new technologies

Performance improvement

- Product portfolio management
- Pricing strategy
- Cost reduction

Equipment and Capex

- LCD/OLED factory capex decisions
- Strategies for equipment makers

Sourcing strategy (Purchasing)

- Sourcing strategies, especially LCD and medical detectors
- Make/buy decisions

Technology strategy and technology assessment

- Market and commercial strategies for new technology businesses
- Market tracking services for corporates monitoring technology

Partnering and alliances

- M&A candidates and assessments
- Alliance formation support
- Post merger integration planning

Professional advisory and business planning

- Specialist insights for bankers, equity investors and other consultancies
- Reviews of business plans and models (Strategic audits)

Strategies for materials providers

- Strategy support for materials providers in the FPD, SSL, and PV markets
- IP and pricing plans