Equipment positioning and market entry in the display industry:

February 2019

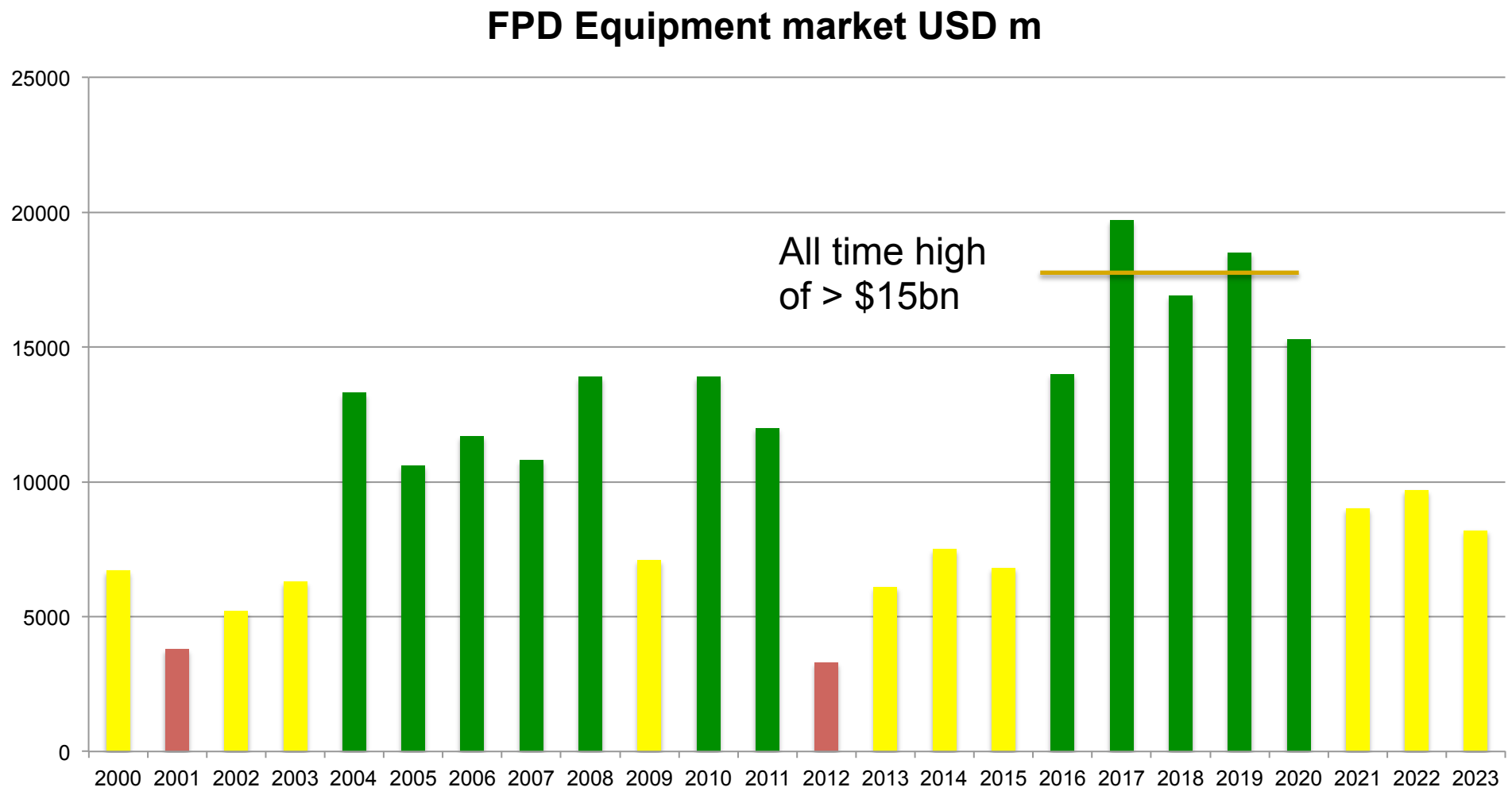
Context

- Hendy Consulting is a strategy provider to the display market and has been advising players for nearly 15 years
  - We advise display companies, materials companies and equipment players on opportunities in the display market
- This presentation seeks to distill some of our case examples into 10 main ideas that players seeking to offer (novel) equipment can use
- The reality of the situation of course is more complicated than a few rules, so we also present out methodology for looking at the opportunity for a new tool/process, in case this helps others structure the analysis
- The areas of current high interest of course will be related to the hot topics of the winter of 2019: the other areas should have shelf life beyond that
- As always with our executive briefings: we appreciate your detailed critique!

Source: HCL

The equipment industry is currently riding a very high wave

Years of more than $10bn equipment spend indicated in green



Source: IHS, HCL
IHS Q3 2018 data and 2006 data

Display industry market map: Selected players and applications

Plus effective number of real players

Source: IHS, HCL, DSCC

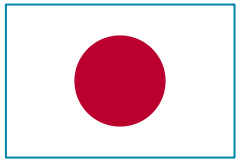
Display equipment market: Market map of selected players by country

Some of the larger firms indicated

Japan

SCREEN, TEL, JSW, ULVAC, Nikon, Canon Tokki

Nissin, VTech, Shibaura, YAC, Panasonic JOLED



USA

Kateeva, AMAT

Korea

Viatron, Avaco, WONIK, HB Tech, Philoptics, AP Sys

Iruja, KC Tech, DMS, SEMES, SFA, Jusung

Invenia, ICD, YAC, Yasu, LG PRI, SNU

Other incl China

AIXTRON, Orbotech, Coherent

Source: HCL

Display equipment top players: Only AMAT has really true breadth

	PVD	CVD	Litho	TFE IJP	C-D	Evap	LLO ELA	AOI Test
AMAT	✔	✔		✔				✔
ULVAC	✔					✔		
Canon Tokki			✔			✔		
TEL				✔	✔			
APS							✔	
SEMES				✔	✔			
SCREEN				✔	✔			
Kateeva				✔				
Nikon			✔					
Orbotech								✔

Source: HCL

Summary of today's display equipment market:

- The 2018 display equipment market totaled over $22bn based on DSCC definition which includes automation and C/R equipment etc (IHS is about 25% lower and tends to focus more on just the equipment). Of the equipment that we are focused on here (the main process tools) gave rise to equipment spending of about $10bn of this
  - Of this AMAT, Canon/Tokki, Nikon, TEL and ULVAC get us already to $6.2bn of this (So the top 5 players are 60%)
- The top two countries for display equipment engineering (other than AMAT which is a distributed multinational) are arguably Japan and Korea which have deep engineering skillsets. Korean firms also have relationships typically with LGD or SDC
- Specific new applications within displays (e.g. flex, foldable, punch-hole, ICP or others) do allow for new players to enter the market and the solar/semiconductor equipment players have made some successes in doing so
- Other than AMAT, most equipment players tend to have 2 real application strengths at most (e.g. Canon/Tokki = Litho + Evapouration, ULVAC = CVD + OLED evapouration). We have not yet seen mass consolidation within the display equipment market (TEL-AMAT merger abandoned)
- As underlying trends, the role of lasers, the role of printing and the role of assembly/transfer techniques and the associated test have become somewhat disruptive and new
- The rest of this presentation will now seek to look at the new opportunities being created in the display industry as it evolves and to speak to display equipment marketing challenges

Source: HCL

10 Key points in the adoption of novel tools for FPD. The first chapter we look into in more depth

1. Where are the opportunities? Many new options but high risk
2. The stack matters
3. The link to the material matters
4. Incumbents have greater chances Processes that are understood have greater chances
5. Typical adoption process Display players move like gorillas
6. Be very aware of “LCD like”
7. Ecosystems and partnerships are a good idea to assist adoption
8. Drivers of value in use and display company economics
9. Customer strategies matter
10. Understand value chain discontinuities

Source: HCL

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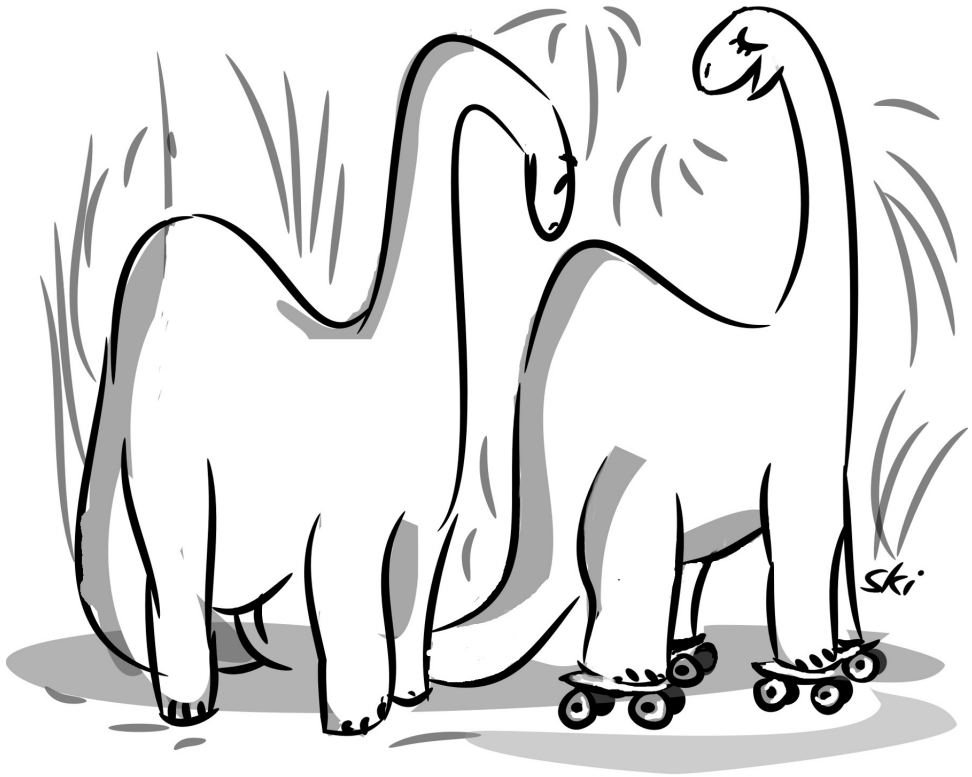
Where are the opportunities?: Display Industry is currently pursuing “Innovate or Die” approach



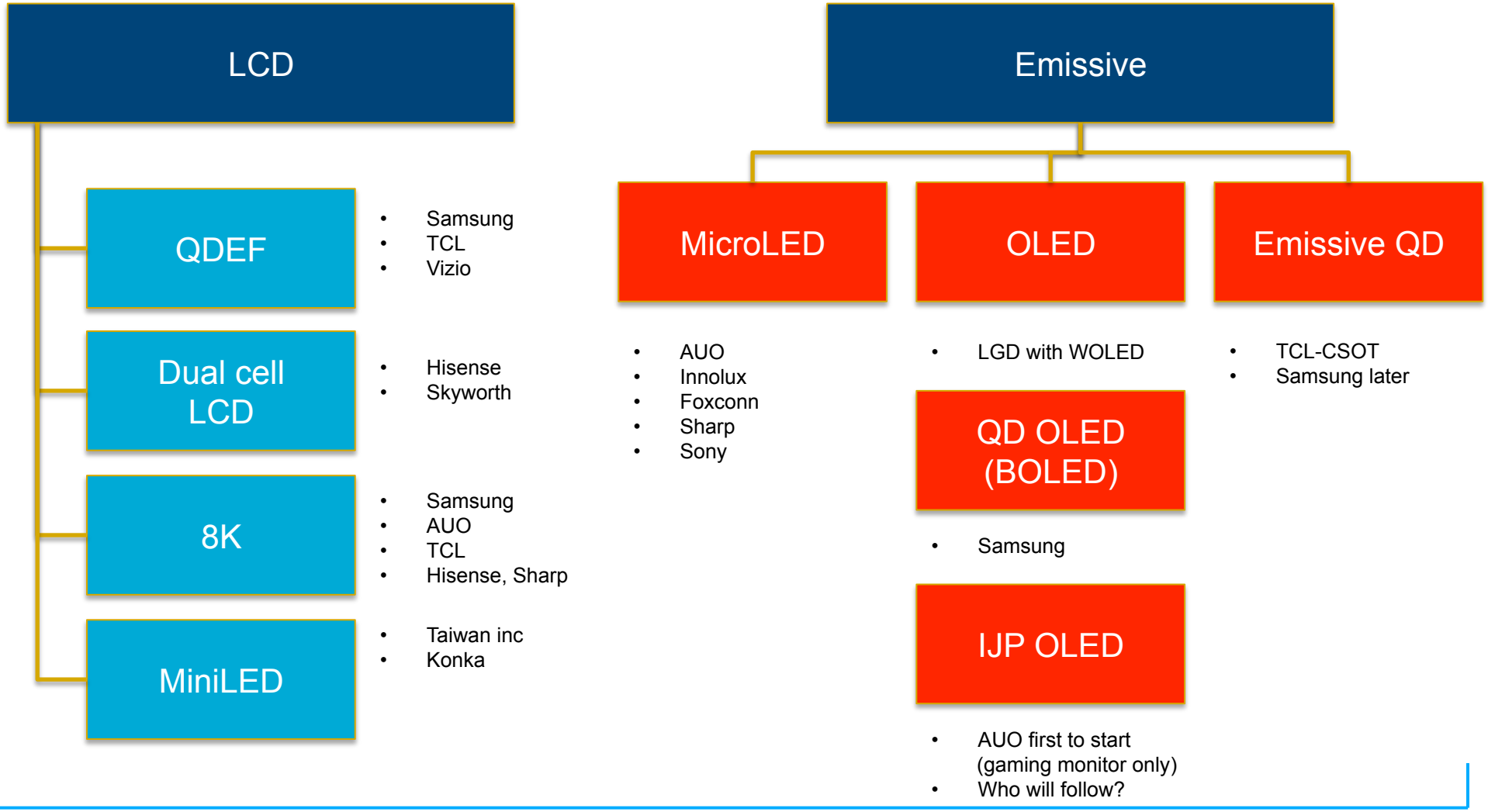
Innovate or die.

CartoonStock.com

- Current display industry is concerned about margin compression due to systemic oversupply caused by the ramp of Gen 10 fabs: many players seeking to redefine premium through an innovation agenda

Source: Cartoon Stock

1 Where are the opportunities?: Current large panel technology push covers many new technologies



Source: HCL
See our separate
"Innovate or Die" piece

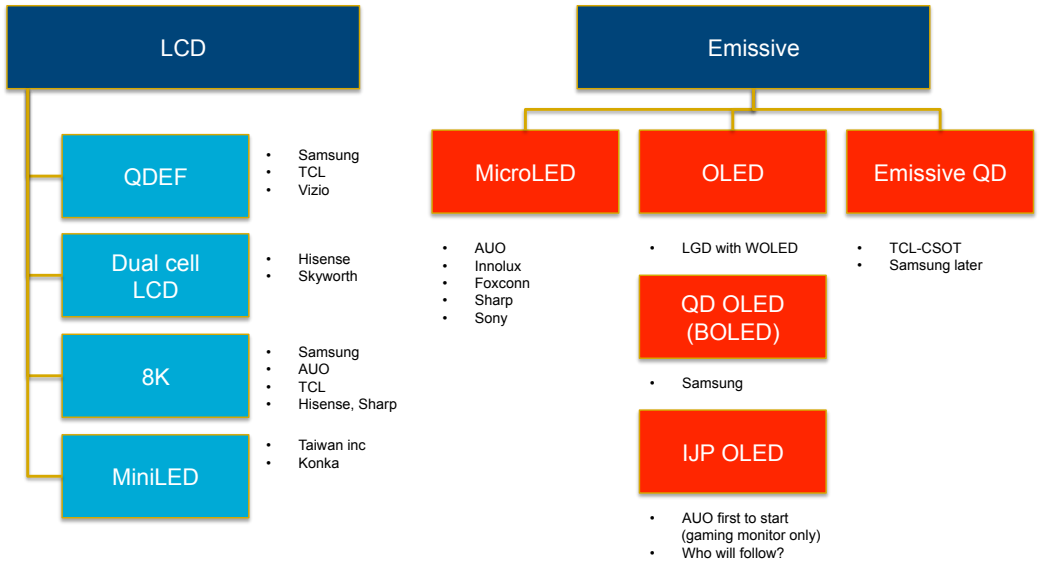
1 Where are the opportunities?: Current small panel innovation agenda

- Punch hole displays Notch displays
- Flex OLED and foldable OLED
- MicroLED small panels (especially wearables)
- VR-AR Microdisplays (Near to eye)
- Increasing display performance across all environments (role of reflective, emissive, other)

- For now the major innovation of the last 3 years has been the role out of flex OLED displays now moving towards foldables and rollables
  - Additionally the changes to camera position etc though notch and punch hole displays as the body coverage of the display increases
- MicroLED also being applied to wearables as one of the first target markets for the technology with the same implications for mass transfer and testing equipment
- Continued innovation around near to eye concepts and AR-VR imagers for both professional and consumer applications: these require very high resolution patterning techniques
- Overall ongoing innovation in display performance in reflective, transmissive and bistable categories

Source: HCL

1 What do these technology push exercises mean for opportunities in equipment?



- Punch hole displays
  Notch displays
- Flex OLED and foldable OLED
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- Increasing display performance across all environments (role of reflective, emissive, other)

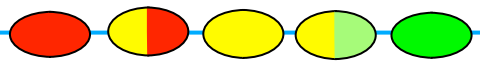
- Tools for mass transfer and binning/assy/test for MicroLED and MiniLED
- IJP tools for large Gen RGB and QD OLED/QDEL or WOLED evaporation systems
- Coaters for QDEF and QDOG

- MicroLED mass transfer/binning/test and assembly tools
- CCL/high resolution litho approaches for high resolution VR-AR
- LLO-Spun PI-other tools for flex and foldable
- Tools for punchhole (lasers) etc

Source: HCL

1 Equipment opportunities in each technology:

	Size	Unmet needs	Current processes	Materials used and implications	Summary
OLED IJP + Evap		Yes	Evaporation for WOLED	Soluble OLED emitters+hosts	One of the largest new equipment opportunities
QD OLED		Yes	IJP for QD (or C+Litho)	Inorganic QDs	Immature Samsung approach may create transitionary equipment options
MicroLED		Yes	Under development	Very small MicroLEDs	Many equipment opportunities across mass transfer, CCL, assembly and test
MiniLED		-	Novel transfer + assembly needed	MiniLED packages	Some of the current SMT machines can address here but application specific kit might be helpful
Notch-punch hole innovations		Yes	Lasers needed for punch-hole	-	New lasers needed for punch-hole applications
AR-VR small displays		Yes	New approaches needed for CCL	-	High resolution patterning techniques required beyond FMM limits
Flex OLED and foldables		Yes	LLO-Spun PI etc	Flex hardcoats/ cover films + others	Ongoing need for yield improvement here and new materials for the foldable stack
Emissive QD		Yes	May need adapted processes	Cd and non-Cd QD emitters	New equipment opportunities will likely be based on IJP



Source: HCL

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It has to be said that many of the opportunities will be with Chinese customers: Chinese equipment players will be new important competitors

Examples from the 2018 strategic emerging industries list (1/2)

Main	Main Category	Sub-code	Sub Category	Vital products & Services
1.2.1	NOVEL ELECTRONICS PARTS AND EQUIPMENT	3562*	Semiconductor production	• IC production equipment • IGBT production equipment • LED production equipment • Crystal growth a wafer production equipment
		3569*	Other equipment and production	• Sputter • ELA • Organic evaporator • OLED ink jet printer • Coater for semiconductor production • Sputter for semiconductor production • Etcher for semiconductor production • Auto lamination equipment • TFT LCD equipment • OLED equipment • SMT equipment

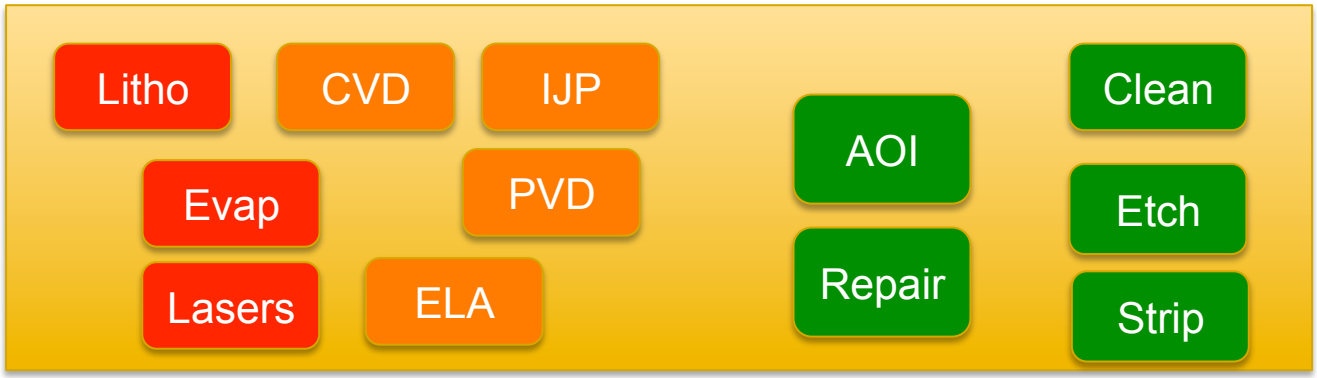
Source: Strategic Emerging Industries name list 2018 | IHS Markit

- The arrival of Chinese competitors in the equipment arena (due to government policy initiatives) will create new dynamics in the display industry
- What may well be interesting is the attitude that incumbent technology leaders will take to licensing IP or forming partners (with local SOEs) in the face of strong domestic competition

Source: HCL

1 Different parts of the equipment industry are also competitive to a different levels:

Least competitive today (oligopolistic)



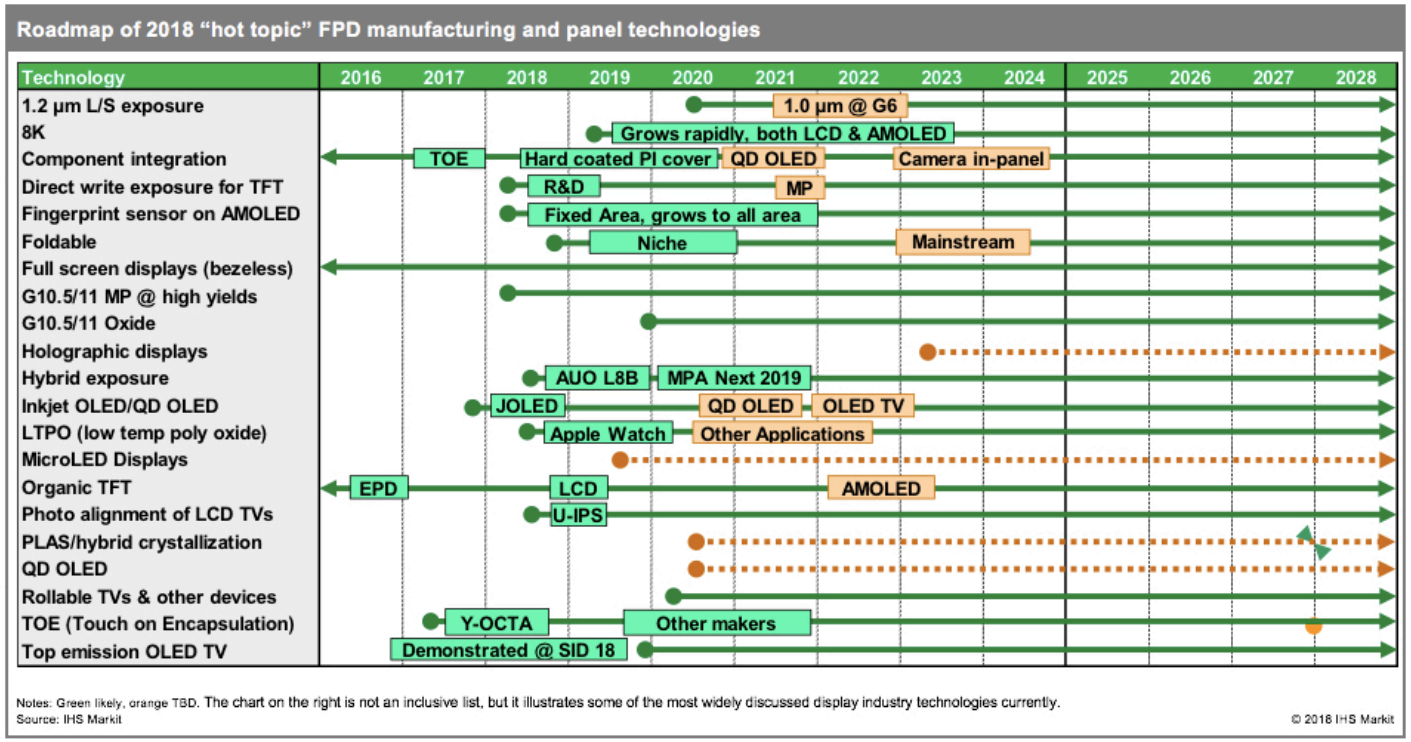
Highly competitive (Many players)

1-2 players 3 players Many players

- Different tools have different levels of competitiveness
- That being said, at certain specs or Gen sizes (e.g. Gen 10) there are areas of effective monopoly (e.g. Nikon for Litho and ULVAC for PVD at Gen 10)
- There are always ongoing needs to put down different materials at higher tact or lower cost that form the basis of ongoing equipment and material innovation
- We would imagine that Chinese players will immediately focus on the simpler applications here first (the ones on the right above) before upskilling

Source: HCL, DSSC

On top of this, innovations in TFT always provide for equipment innovation opportunities:



- Of the 21 innovations shown here by IHS, then around half of these are innovations based on new equipment approaches
- Some of the processes described here (and on the former opportunity slides) will allow new players to enter the display equipment market

Source: IHS

1 Where are the equipment opportunities: Summary

New display technologies

- New options to support mass transfer assembly and test techniques (and others) for MicroLED and separately MiniLED (more serviceable by the SMT players)
- Implications for IJP of QDEL, QD-OLED technologies and the handling of Cd and non-Cd based QD materials

New players (China) will create new options and new competitors

- Options for players to consider how to deal with the competitive threat of the new players in China

Process implications and long term unmet needs

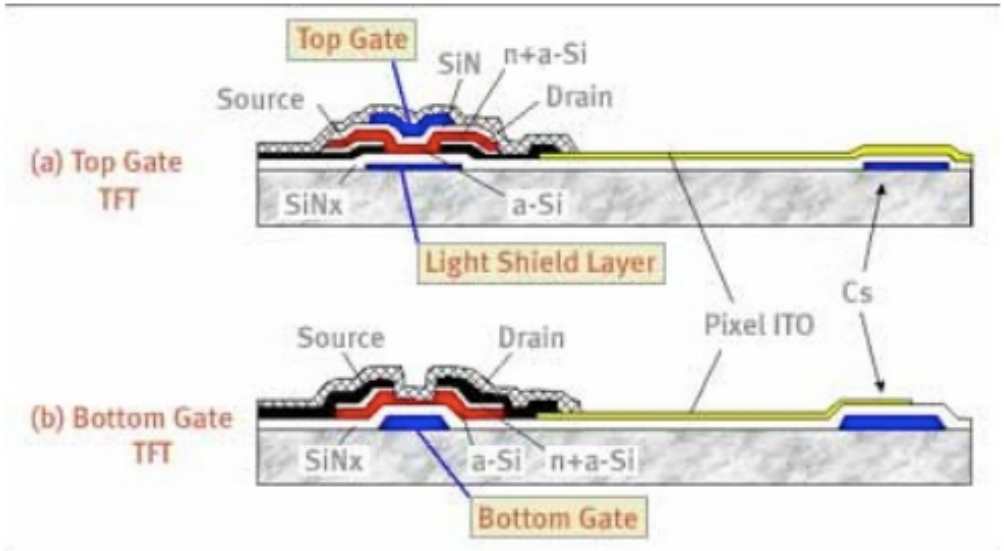
- We see about half of the current innovation agenda as shown by IHS to be equipment driven including:
  - Finer litho
  - Direct write
  - Gen 10 oxide
  - Hybrid exposure
  - PLAS
  - …
- Long term unmet needs remain
  - A simpler TFE solution
  - Top emission large panel OLED including backplane implications
  - ICP (In cell polarisation)
  - High speed ALD
  - High resolution OLED patterning

Competitive structure

- We would expect Chinese engineering firms to enter the more competitive display equipment markets first
- Some players may seek to eliminate the monopolies that some players have in certain markets or Gen sizes

Source: HCL

2 The stack matters and the process matters: players need to understand load/unload and cluster tool implications



- This seems like a simple thing to say, but the implication of the the positioning of the tool/material in the overall flow and the implication for the layers above and below are critical
- Moreover, some new players underestimate the benefits incumbent in cluster tools (e.g. OLED clusters, or PVD/CVD clusters) as a way of reducing tact times and reducing the need for handling/load/unload
- Given the overall risk profiles that display companies handle, this tends to lead to fairly conservative equipment adoption behaviour: a new tool has to solve a fundamental *unmet need* usually to force adoption

Source: HCL

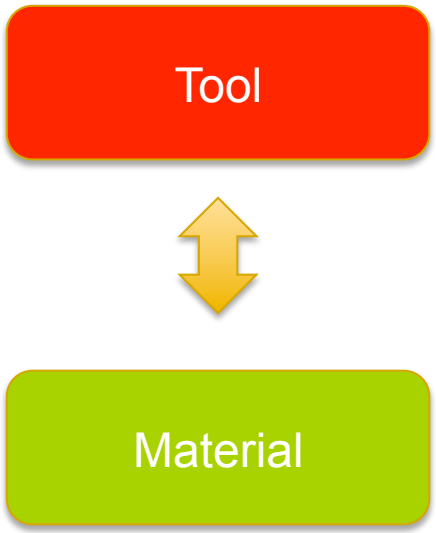
3 The link to the material matters:

- This seems an obvious thing to say, but the detailed link to how your material is processed: in what tool, in what way, at what speed and with what uniformity matters

- Often development of a novel electronic material will depend critically on a partnership with an equipment partner
  - This sets up a three way market push and often the achilles' heel for the project is the difference in speed between material and equipment development timelines

- We have tended to find that display R&D departments think of themselves as specialists in particular in PVD/CVD and therefore tend to lean towards materials deposited with these despite the fact that they do understand and use a variety of organics and coated/ evapourated materials elsewhere in the line

- Tact
- Uptime
- Reliability
- Quality
- Reputation
- Material-tool interaction



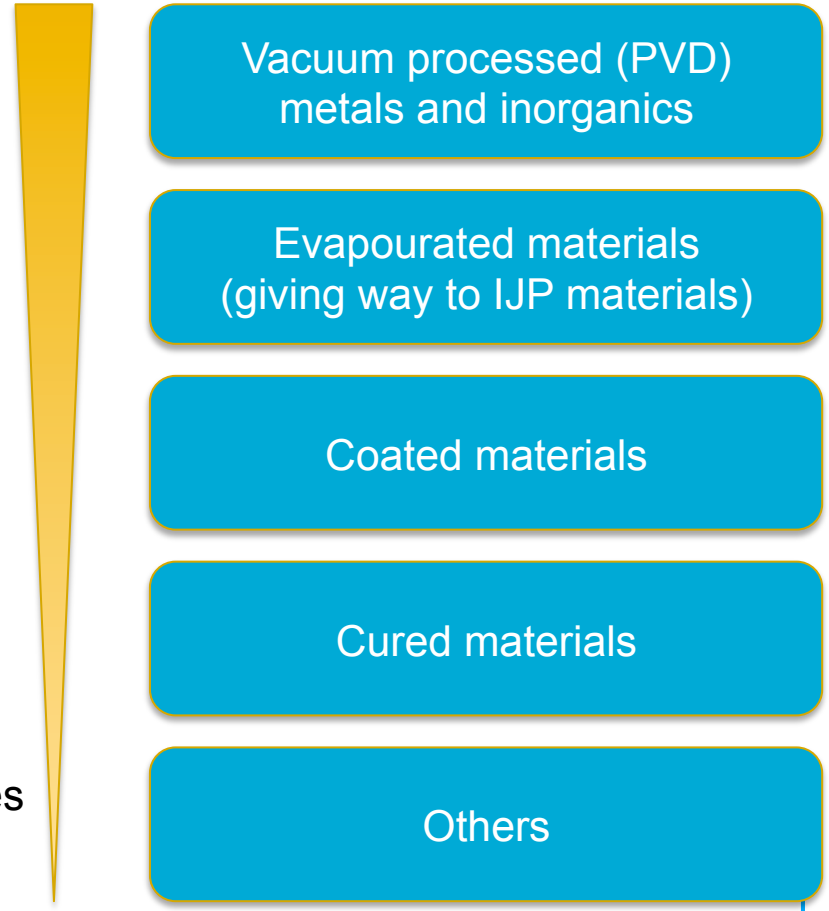
- Lifetime
- Processability
- Performance
- Degradation issues
- Storage concerns
- Optical and electrical performance
- Interaction with tool (e.g. print head)

Source: HCL

4 Incumbent processes (e.g. PVD/CVD) have better chances. Good enough often wins

- Incumbent technologies are better understood
- Most display engineering companies tend to have a better understanding of PVD, CVD and perhaps evapourated materials than perhaps other techniques
  - Yes, coating is an approach used heavily in display making but we have been real conservatism of display players for example to adopt coated solgels
- Gradually an understanding of the role of additive printing of materials is beginning to emerge (based on the success of the TFE application) and also the role of lasers in the display process also more commonplace (moving from LLO and ELA core processes to punch-hole and other areas of display making)

Most common material/tool combinations (decreasing popularity)



Source: HCL

5 Adoption processes: Display industry players move as a pack and watch the lead player

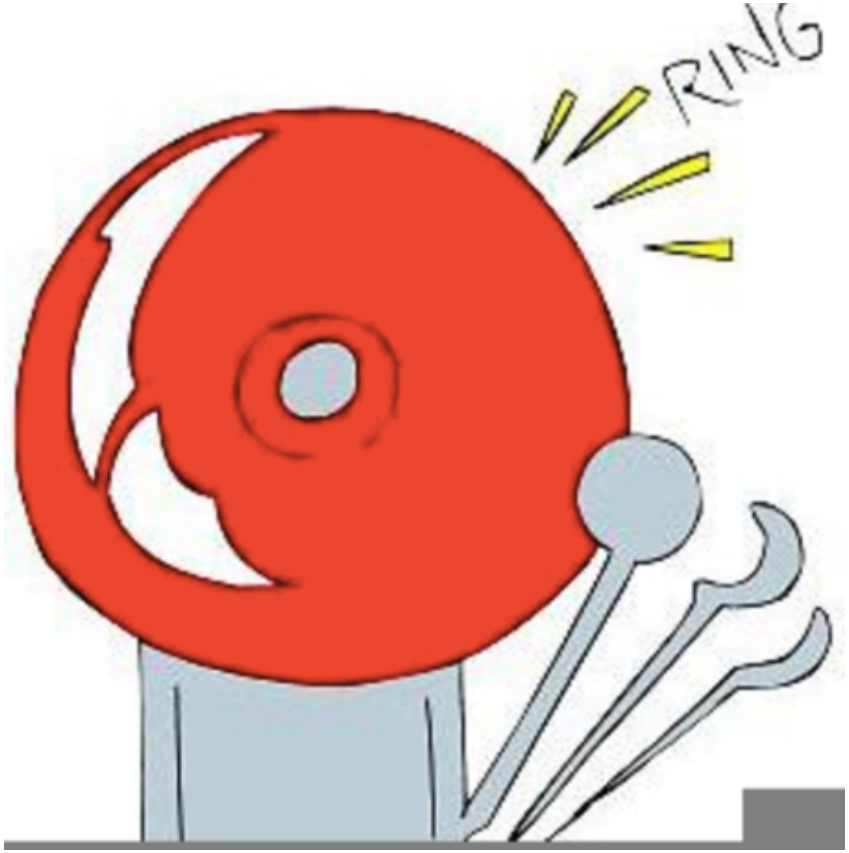
- Newbies to the display equipment industry tend to believe that they will be in volume production faster than actually transpires
- The display industry tends to move “as a pack” on adoption of new equipment approaches
  - If Samsung or LGD adopts the tool and it works successfully this leads to a skittering across the whole industry
- The implication for a new player is that 80% of the effort may be made on the first customer, the first sale – and then 20% on expansion thereafter

Source: HCL

6 Beware of “LCD like” when talking about new tools or equipment flows

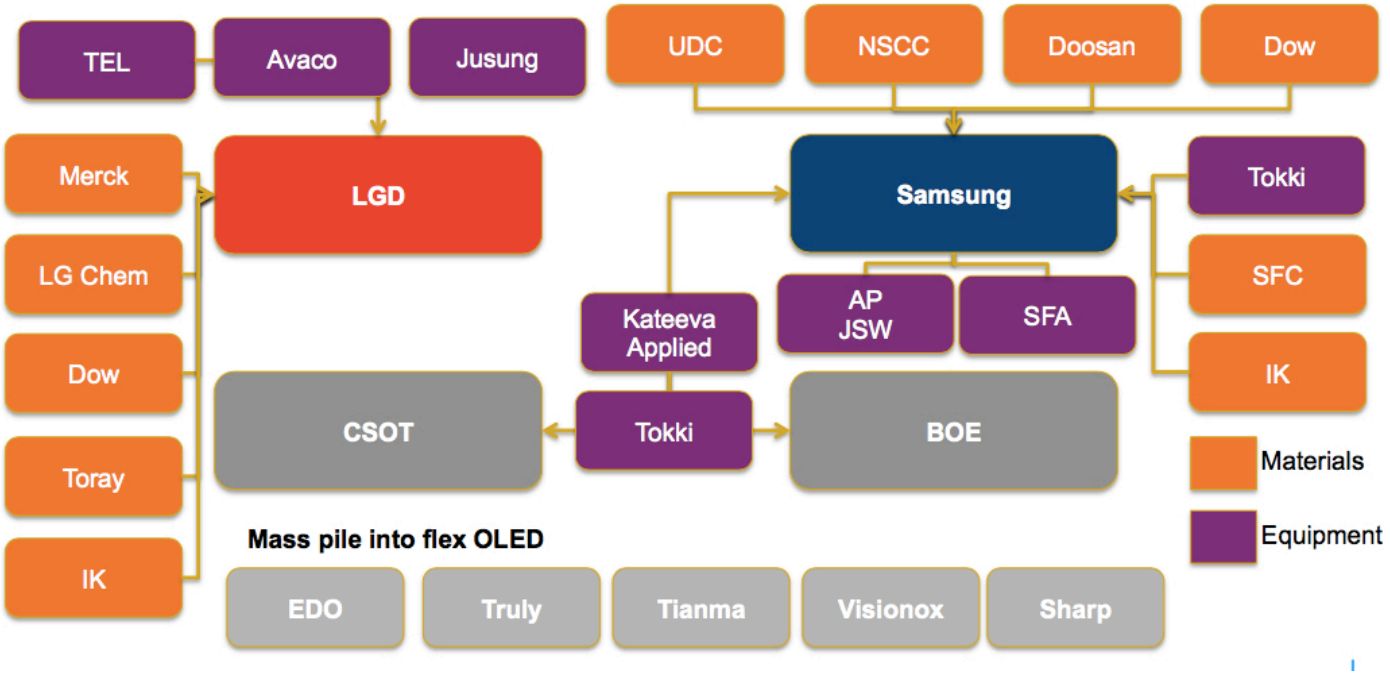
- We have quite some experience working on new display technologies or new equipment technology approaches that owners describe as “LCD-like processes”

- This always sets of alarm bells for us – any changes from standard LCD flows (which are usually very exhaustively optimised) create very real problems for display engineers
  - If you imagine that your $4bn factory can only work if all processes function together and then deliver a margin of 0-10% EBIT and a single tool not working (out of perhaps 30-40 in a flow) puts this at risk, then you will understand how a display engineer might think



Source: HCL

7 Ecosystem management is a strong way to proceed:



- The barrier today to introducing a new novel tool is high: perhaps this can be managed a little lower though the active use of ecosystem management (or at least coordinated information flow between key parts of the system)
- We tend to believe that partnering in the equipment industry is going to become more and more important in the future

Source: HCL

8 Drivers of value in use:

- There are many reasons why a tool could be perceived as adding value to a display player: and the top reason for the adoption of a new tool or process approach would probably be new functional value (that is unable to be delivered in any other means)

- Display players are endlessly seeking options for ASP increases (see the “Innovate or die technology slides earlier), so product performance is also a key driver of value

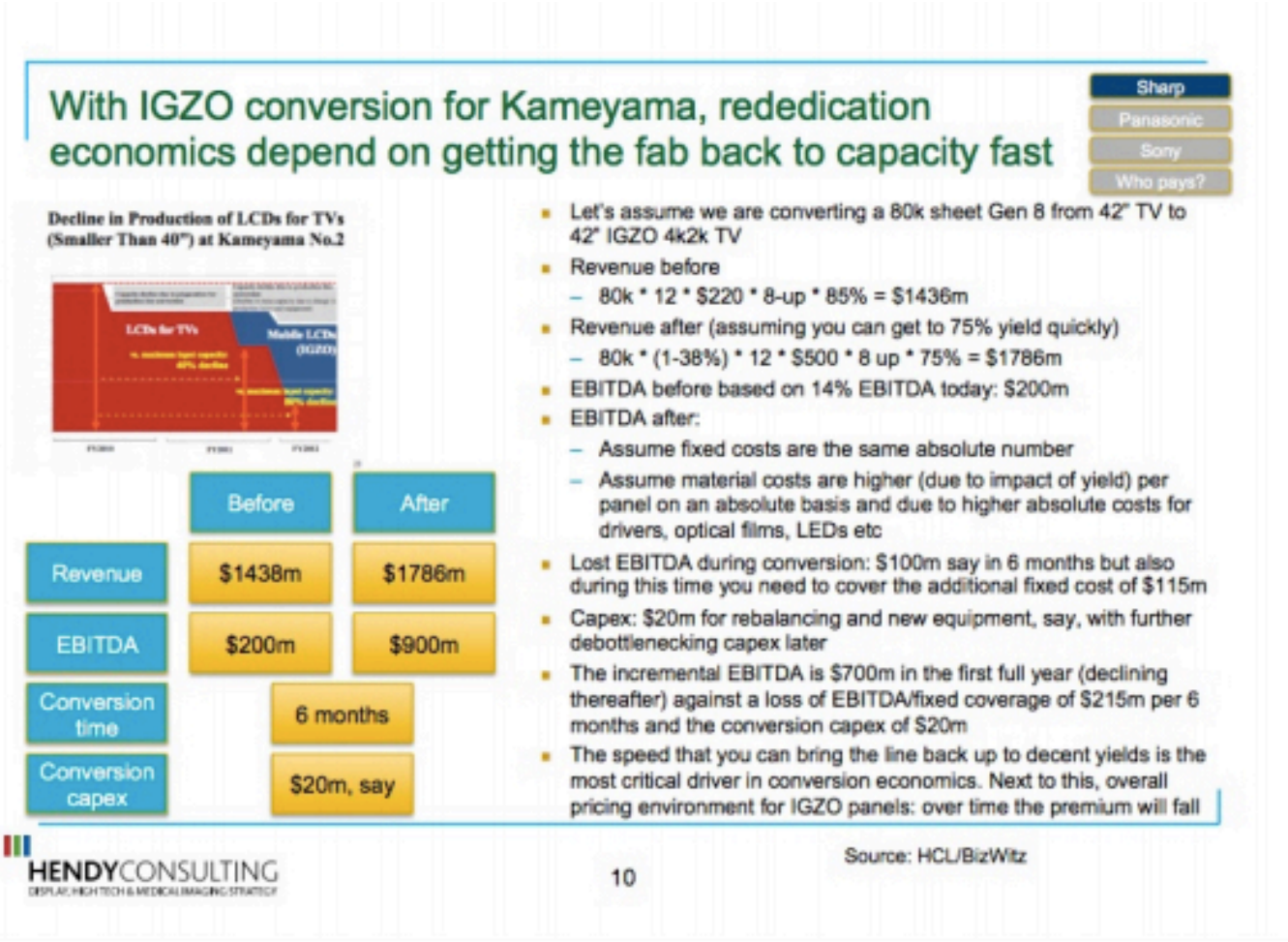
- There are a range of other benefits including quality, cost, cost structure, product simplification, footprint, consumables usage and other value drivers but the display industry tends to value innovation or product value drivers the most

Drivers of value with some of the more important at the top

Source: HCL

8 …and be aware of display company economics:

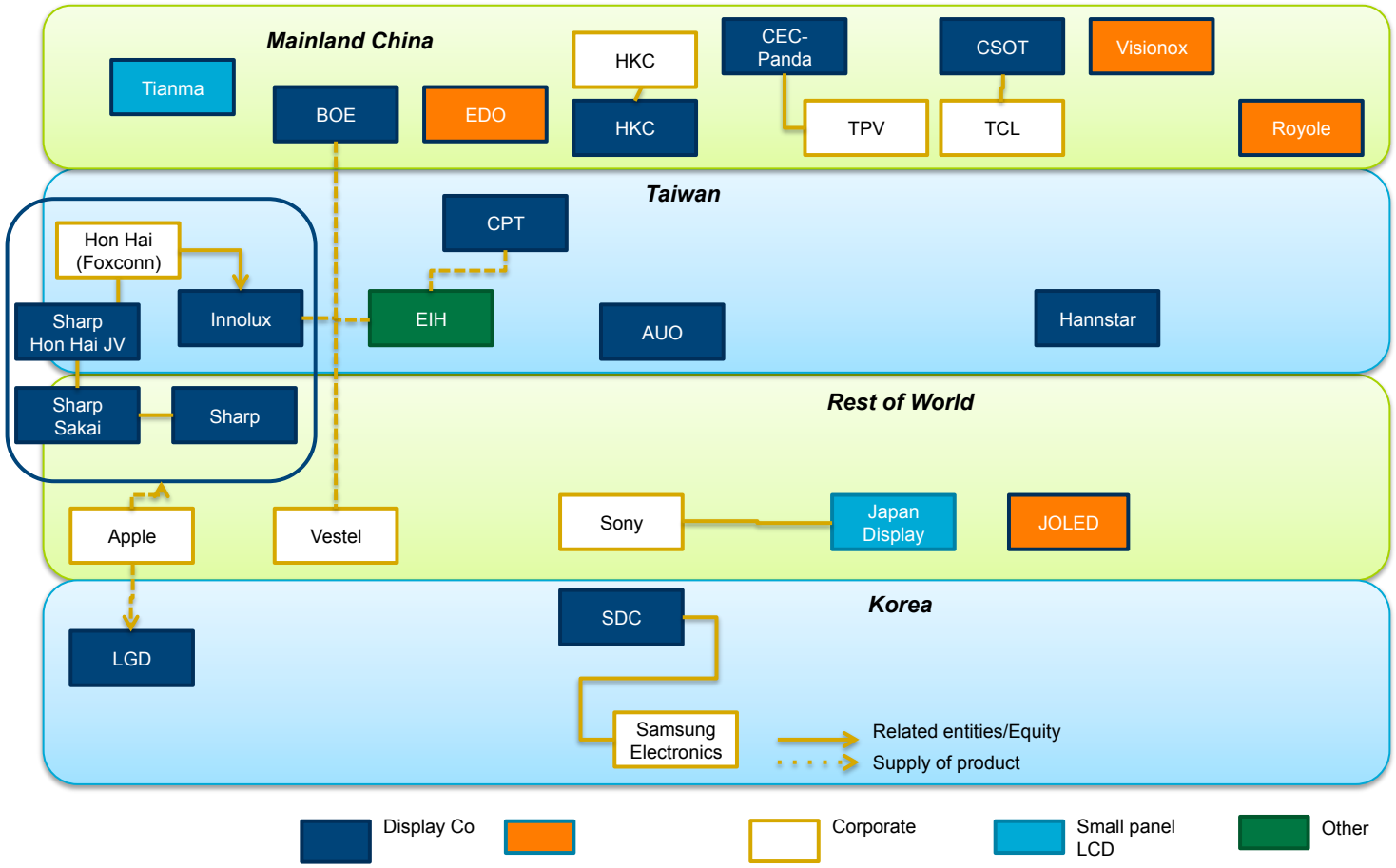
- Overall of course, the tool proposition must reflect the underlying display economics
- Can the tool vendor understand and describe the proposition to the customer in a way that makes sense to a display engineer?
- This is an example of the conversion economics to IGZO but equipment vendors face this sort of intellectual challenge frequently: do they understand the customer economics?



Source: HCL

9 Customer strategies matter: their businesses and capex requirements differ

- The different players in the industry have fairly different businesses and propensities to consider equipment risk
- The most open minded (yet demanding) customers include SDC and LGD among others
- Some of the second tier players are more likely to be swayed by a price reduction in some cases



Source: HCL

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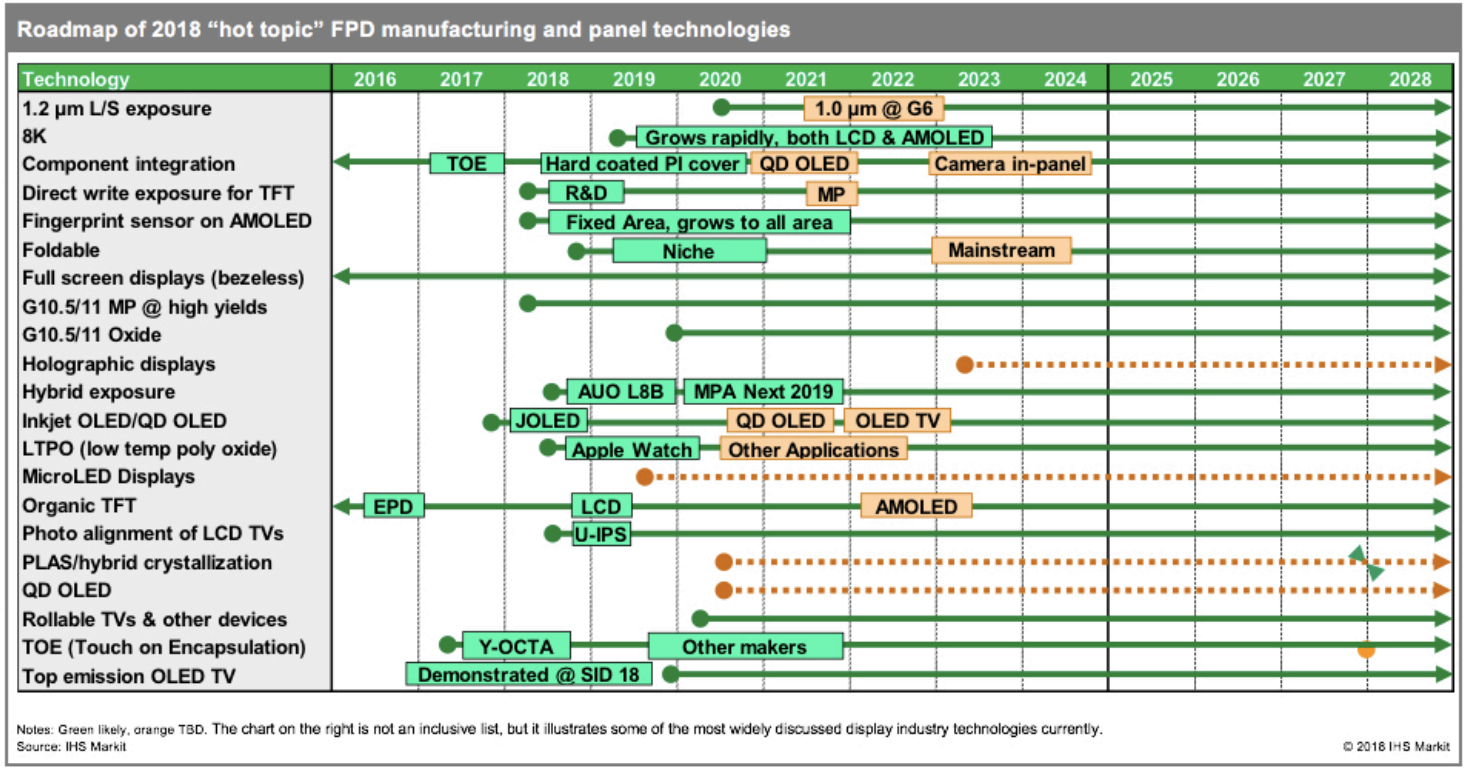
Understand value chain pressures and dislocations:



- We love this technology and process roadmap by Charles Annis
- In it are a number of process dislocations and those things that represent the migration of value across the value chain (e.g. the TOE and component integration options)
- Equipment players should always be aware of the evolving boundaries between display and touch companies, and between display companies and set makers (open cell model for large panel)

Source: IHS, HCL

10 Key points in the adoption of novel materials (Recap)

1. Where are the opportunities? Many options but high risk
2. The stack matters
3. The link to the material matters
4. Incumbents have greater chances Materials/processes that are understood have greater chances
5. Typical adoption process Display players move like gorillas
6. Be very aware of “LCD like”
7. Ecosystems are a good idea
8. Drivers of value in use
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Source: HCL

Final thoughts

- The display equipment industry is in a period of expansive growth with some describing 2020 as shaping up to be a very high year for the equipment industry
- The display industry is also undergoing a massive innovation drive as everyone tries to change the game
  - The challenge at the moment is in managing the very high market risks and to take a risk adjusted approach to new options that are very clearly present: we show 4 different axes to consider new options in the equipment industry: new display technology, role of Chinese competitors, segment competitiveness and process discontinuity drivers
- We wonder whether the equipment industry will begin to consolidate and how it will respond to the threat of the Chinese entrants
- We have a strong service offering for the display equipment community (quals and previous projects follow this slide)
  - Please contact us if we can help with your new equipment idea or in improving your market understanding

Source: HCL

Our offerings:

Growth strategy	Performance improvement	Equipment and Capex	Sourcing strategy (Purchasing)
• Market entry strategy • Business unit strategy • Growth strategies for new technologies	• Product portfolio management • Pricing strategy • Cost reduction	• LCD/OLED factory capex decisions • Strategies for equipment makers	• Sourcing strategies, especially LCD and medical detectors • Make/buy decisions

Technology strategy and technology assessment	Partnering and alliances	Professional advisory and business planning	Strategies for materials providers
• Market and commercial strategies for new technology businesses • Market tracking services for corporates monitoring technology	• M&A candidates and assessments • Alliance formation support • Post merger integration planning	• Specialist insights for bankers, equity investors and other consultancies • Reviews of business plans and models (Strategic audits)	• Strategy support for materials providers in the FPD, SSL, and PV markets • IP and pricing plans

Source: HCL

Our equipment related evaluations:

- QDEF evaluation for equipment options
- QD OLED and QDEL equipment options
- TFE equipment outlook
- OLED IJP equipment outlook
- Barrier approaches equipment options
- OLED equipment options and technologies
- MicroLED equipment implications
- Market entry strategy workshops for novel lithography approach
- Coated semiconductor evaluation and equipment implications
- CF new approaches evaluation
- ALD investigation

- We have looked at a broad range of topics within equipment development to support NPI and to support R&D programmes
- We have an understanding of market drivers and of process technologies, stacks, cost and trade offs

Source: HCL

Services to equipment players:

Services to Equipment players

- Opportunity assessment
- Market entry strategy
- Competitive assessments
- Technology/process assessments
- Factory cost modeling
- M&A target scanning
- Cost modeling
- Value in use assessments and link to tool pricing
- Market outlook assessments (and understanding of capex view of DSCC vs IHS)
- Customer strategy and fit
- Partnership assessments and execution

- We offer a broad range of services to the display equipment industry
- We have the combination of technical and commercial knowhow to put together rounded assessments of market options
- We have quite a long list of previous assignments for display equipment players (See prior slide)

Source: HCL