Europe Technology

Initiation

Atomic Layer Deposition: Digital Enabler for the evolution of advanced semiconductors; initiate on ASMI at Buy

Improvements to lithography techniques (such as Extreme Ultraviolet Lithography) have been a strong driver of continued node shrinkage at the leading edge in recent years, facilitating more and more powerful chips at lower cost. That said, we now see scope for advanced deposition technologies to play an increasingly important role in the future roadmap of chip-making and therefore warrant characterisation as key European Digital Enablers within our framework. In particular, we expect greater adoption of single-wafer Atomic Layer Deposition (ALD), which allows greater precision than traditional techniques in placing materials onto wafers, a process which proceeds in tandem with the printing onto them of designs for transistors, effectively the brain cells of the chip. This will enable upcoming innovations in transistor density and architecture (e.g. Gate-All-Around) to drive continued performance improvements as the Semis market expands from $600bn today to $1 trillion by 2030, on our estimates. In this report, we explain this technology and its position in the chip-making value chain, explore potential advantages and applications, and contextualise against dynamics in the broader Wafer Fab Equipment landscape. In addition, we initiate on ASM International, the market leader in this area of the semiconductor equipment market, with a Buy rating and a 12-month price target of €365. Our rating is predicated on a bullish view on both the importance of ALD and associated robust multi-year growth opportunities such as the transition to Gate-All-Around transistor structures, continued node shrink at leading Logic/Foundry players, and favourable end-market exposure relative to other semicap players.

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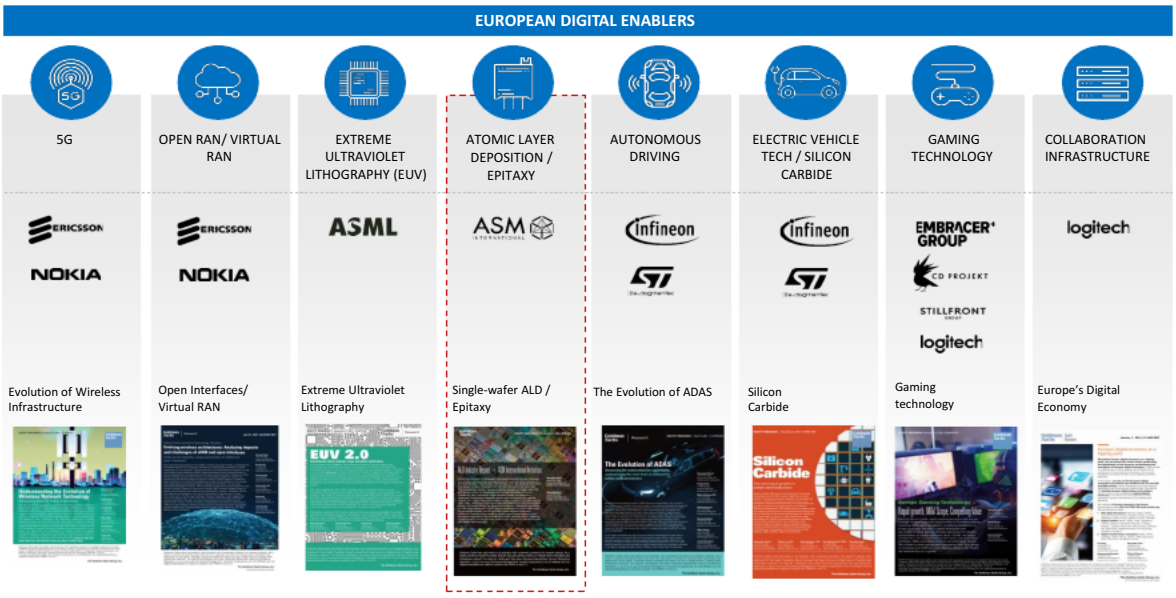
Exhibit 1: We see Atomic Layer Deposition and Epitaxy, tech used in chip production, as key Digital Enablers that can see increasing adoption on a multi-year basis
European Digital Enablers



Source: Goldman Sachs Global Investment Research

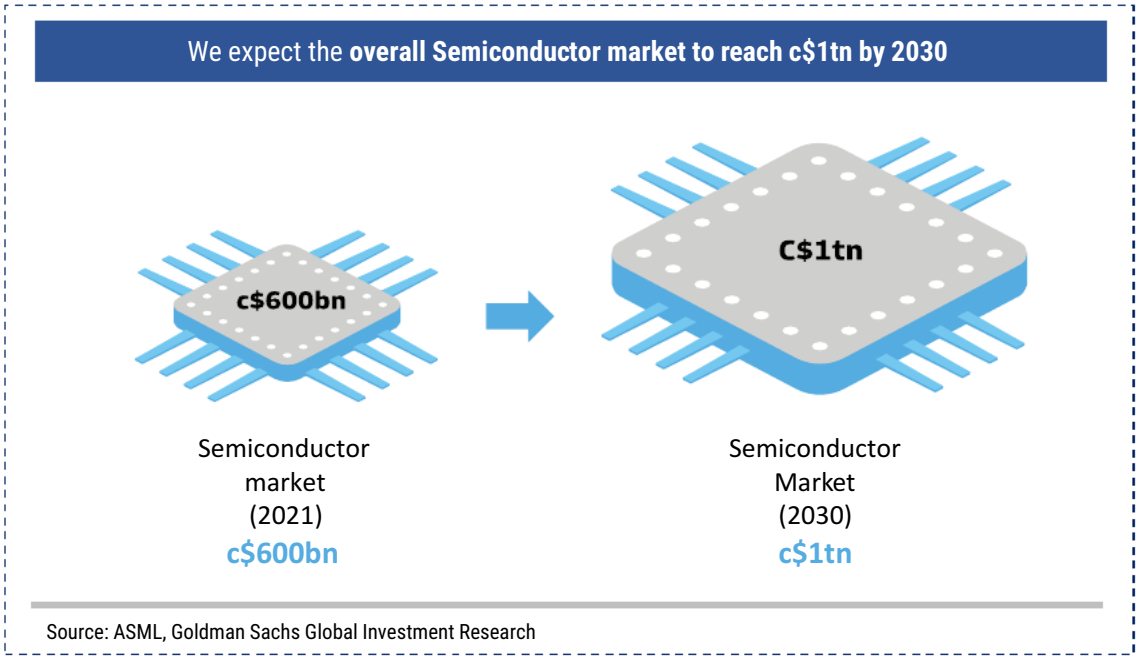
Atomic Layer Deposition and Epitaxy, the most advanced technologies for leading-edge deposition, to be key Digital Enablers of the future chip-making shrink roadmap

While improvements to lithography techniques (namely Extreme Ultraviolet Lithography) have been a strong driver of continued node shrinkage at the leading edge in recent years, we see scope for advanced deposition technology to play an increasingly important role in the future roadmap of chip making on a multi-year basis. In particular, we expect greater adoption of single-wafer ALD and Epitaxy, which offer meaningfully higher levels of precision than traditional techniques in depositing materials onto silicon wafers, a process which proceeds in tandem with the printing onto them of designs for transistors using lithography in order to create transistors (effectively the brain cells of the chip). This is required to enable upcoming transitions in transistor density and architecture to produce more powerful chips, such as the shift to Gate-All-Around (and move to 3D DRAM), as these new designs involve more complex topographies onto which materials can only be efficiently (and accurately) placed using such techniques (rather than more basic – and less accurate – approaches such as Physical wafer deposition). As such, they warrant characterisation as key European Digital Enablers within our framework, in our view, given their role in facilitating cost-effective growth in the global semis market from $600bn today to $1 trillion by 2030E and opening up robust multi-year TAM expansion potential for well-positioned semicap players.

- **Single-wafer Atomic Later Deposition (ALD) is the most advanced technology available for depositing ultra-thin films**, a crucial step in the iterative process of building a semiconductor chip, ***one atomic layer at a time*** **in the most critical layers of leading-edge** technology nodes, thereby allowing deposition of materials at smaller node sizes and where semis are produced using more complex designs such as Gate-All-Around, thus facilitating the production of increasingly powerful chips.
- **While ALD is a broad platform** used to deposit several different types of materials, **Epitaxy (Epi)** is a similar (albeit more niche) technology, used to **deposit highly controlled, thin, silicon-based *crystalline* films that exactly match the underlying substrate**, enabling chip makers to improve the **electrical properties** of the chip, such as the **speed of electron movement, enhancing transistor performance.**
- The **market for ALD and Epi tools is currently only ~$2.3bn (2020), vs a broader Wafer Fab Equipment (WFE) market of >$80bn (with GSe forecasting a WFE market of $94bn in 2022),** serving a **c$600bn global semiconductor industry that we believe is set to expand to $1 trillion** by the end of the decade. We expect these technologies to **rapidly grow and take share within WFE**, as leading-edge **Logic/Foundry players continue to transition to smaller and more powerful nodes** (driving the need for more complex deposition techniques), as well as strong uptake related to the **upcoming transistor architecture shift to Gate-All-Around structures (for logic chips) and, eventually, 3D DRAM in the memory space.** As such, players such as ASM International, a leading single-wafer ALD tool manufacturer, expect the **combined single-wafer ALD and Epitaxy market to grow to >$5bn by 2025**, suggesting its share of WFE will expand by ~50%, in our view.

We see WFE processes such as lithography and deposition as key in facilitating continued growth of the **c$600bn global semiconductor industry that is set to expand to $1 trillion** by the end of the decade (and thereby support continued significant spend on semiconductor capital equipment long term).

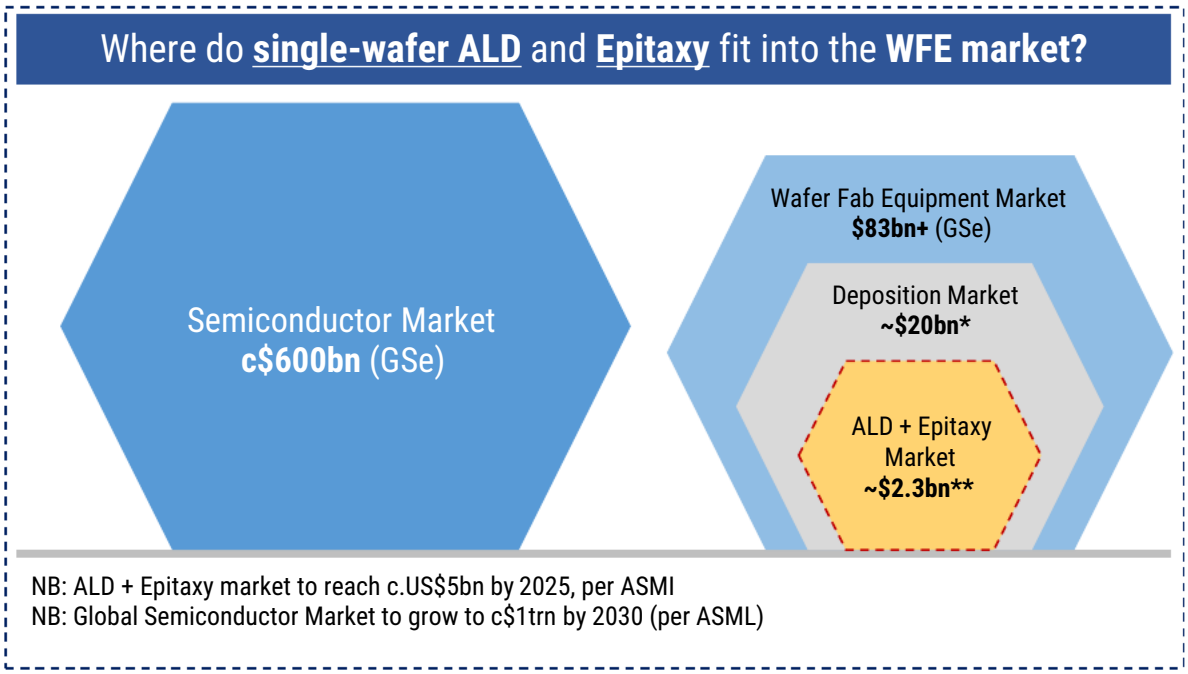
Exhibit 2: We expect the overall semiconductor market at c.$1 trillion by 2030 driven by a transition to smaller and powerful nodes, highlighting strong growth potential for companies



Source: ASML, Goldman Sachs Global Investment Research

Exhibit 3: Single-wafer ALD and Epitaxy are niche areas within the $83bn+ global Wafer Fab Equipment market, but are expected to gain significant share in coming years

Market size (GSe) for 2022 is $94bn



NB: Market size (GSe), $bn, 2021; *per ASMI, deposition was 20-25% of the WFE market in 2021; **2020

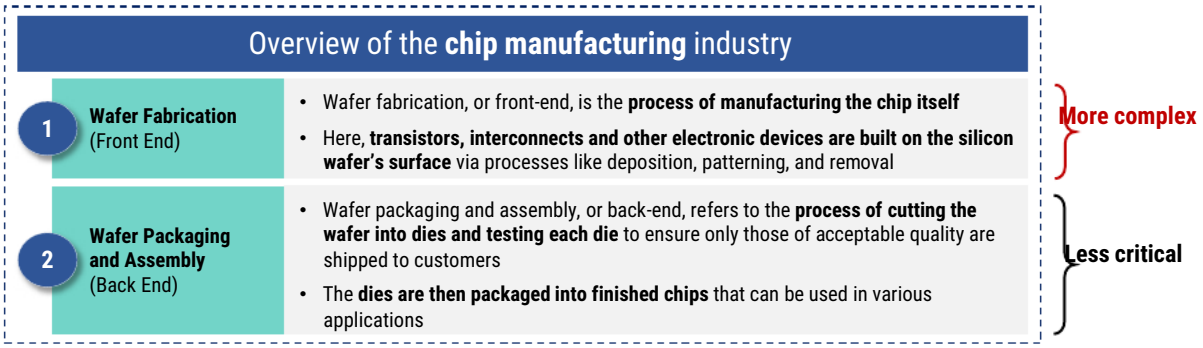
Source: Gartner (Global Semiconductors), Goldman Sachs Global Investment Research, ASM International

Advanced deposition techniques complement other required chip-making processes such as lithography and etch, and comprise some of the highest value-add areas of semicap equipment, in our view

The manufacturing process of a semiconductor chip can be broadly divided into two separate categories: 1) Front-end Wafer Fabrication and 2) Back-end Wafer Packaging and Assembly, and advanced deposition is part of the former. We see the former as involving greater complexity and note this is where ALD/Epitaxy are relevant.

- **Front-end wafer fabrication involves the production of the chip itself**, as transistors, interconnects, and other infrastructure that enable the chip to function are built onto the silicon wafer's surface, via processes such as **deposition, lithography and etch**.
- Separately, **back-end wafer packaging and assembly refers to the process of taking completed wafers and cutting these into several individual dies**, which are then **tested**, **packaged,** and shipped to customers, as explained in the exhibit below.
- **Single-wafer ALD and Epitaxy**, as detailed in greater depth later, are critical technologies for the manufacturing of the chip functions and hence are **best characterised as front-end wafer fabrication processes.**

Exhibit 4: The manufacturing process of a chip can be divided into wafer fabrication (front-end) and wafer assembly (back-end)...



Source: Goldman Sachs Global Investment Research, STMicroelectronics

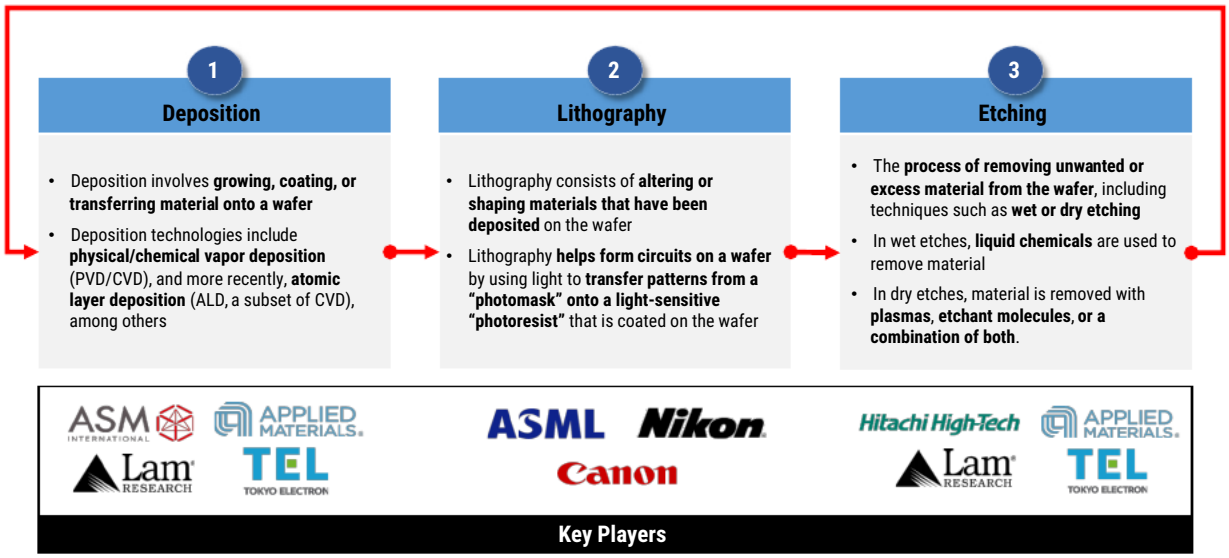
As detailed below, front-end wafer processing involves several iterations of three key production steps: 1) Deposition (transferring material onto a wafer), 2) Lithography (printing circuitry patterns onto the wafer), and 3) Etching (removing materials to reveal the intended patterns). Single-wafer ALD and Epitaxy are two of the most advanced deposition techniques available today and are typically reserved for the most critical layers at leading-edge nodes, representing high value areas of WFE, in our view.

- **Deposition involves growing, coating, or transferring materials onto a wafer, a process which proceeds in tandem with the printing onto them of designs for transistors, the brain cells of the chip.** As semiconductor structures become smaller and more powerful, **more advanced deposition techniques are required**

to meet increasing precision requirements. Consequently, as **traditional deposition techniques such as physical vapor deposition (or more basic forms of Chemical vapor deposition) become less applicable in some situations**, we expect **greater uptake of more precise deposition technologies such as single-wafer ALD and Epitaxy as node shrink continues**, which we discuss in greater detail later.

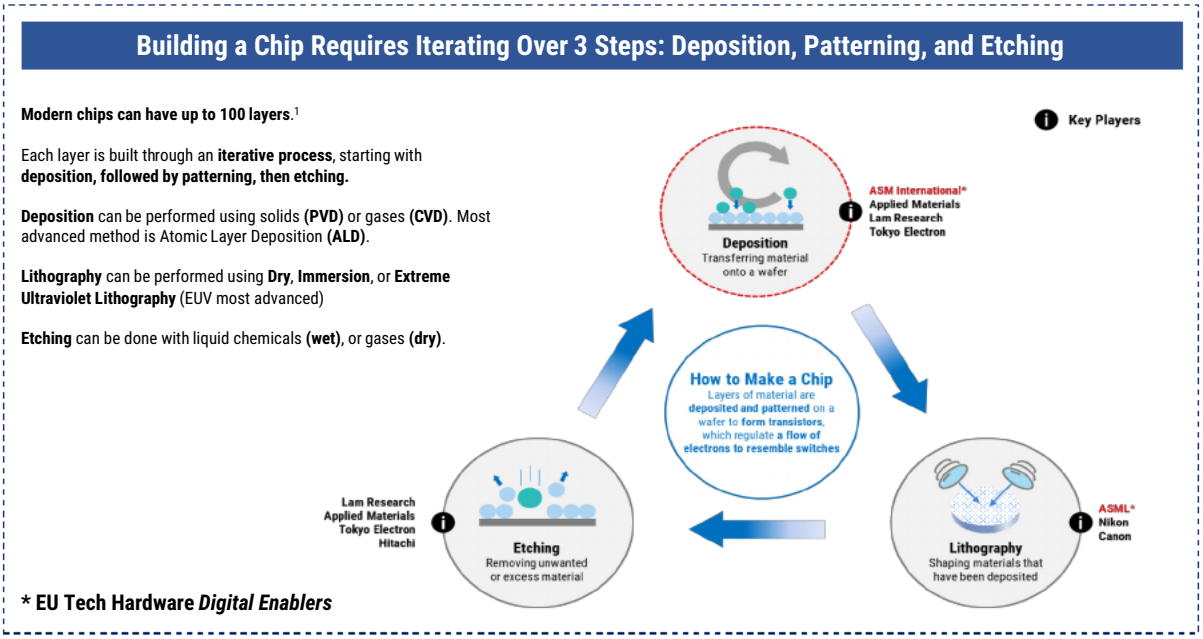
- During **lithography** steps, circuitry patterns are printed onto the wafer by using **light to transfer patterns from a photomask (i.e. blueprint) onto a light-sensitive photoresist** that is coated on the wafer. When light hits the resist, a chemical reaction occurs that enables the **pattern from the blueprint to be replicated onto the resist layer. Since Lithography is facilitating the development of *smaller transistor geometries*,** at which **conventional deposition methods are not able to meet some of the higher precision requirements** (due to ***smaller dimensions***), we see a significant opportunity for more complex technologies such as **single-wafer ALD and Epitaxy that are able to deposit thin films one atomic layer at a time.**
- We note that ASMI, a leading player in the ALD industry, expects that **around 50% of all known elements will be used in the semis industry in the next decade. We see ALD as being the best-suited technology that has the flexibility to deposit a *wide array of materials* (such as pure metals, metal oxides, metal nitrides, and silicon oxide), which are needed to transition to the Gate-All-Around architecture and maintain electrical performance.**
- For completeness, we note that **etching is the process of removing unwanted or excess materials from the wafer** without damaging the layers within the chip structure. For example, if an etching process is designed to create a cavity in the chip, it is critical to ensure the right depth of cavity is created. This report is focused on deposition rather than etch (although clearly it is an important part of the WFE market).
- Overall, **modern chips can often have up to 100 layers**, with each layer built through an **iterative process of deposition, lithography, and etching**, eventually forming **interconnected transistors**, as detailed in the exhibit below.

Exhibit 5: …with front-end processing steps split into 1) Deposition, 2) Lithography, and 3) Etch
Process Steps in Semiconductor Device Fabrication



Source: Goldman Sachs Global Investment Research

Exhibit 6: Building a chip is an iterative process of 3 steps



1. Per ASML

Source: Goldman Sachs Global Investment Research, ASML

While a number of deposition techniques are used across the chip production process, **single-wafer ALD and Epitaxy are primarily used in the production of individual chip components** (e.g. transistors, capacitors and resistors), known as **front-end-of-line (FEOL)**. Critical individual components require the highest levels of materials expertise as far as deposition is concerned and this may be contrasted with

Back-End-of-Line layers (BEOL) where ALD is not a focal point.

- **FEOL production steps have higher requirements for precision and materials expertise** given these chip layers typically contain a **higher concentration of critical components such as transistors, capacitors, and resistors**. This tends to be where ALD is most applicable.
- Conversely, **back-end-of-line** (BEOL) chip layers usually **contain fewer critical components and comprise metal interconnects that are analogous to the plumbing of the chip**.
- In Exhibit 8, we map out the **position of single-wafer ALD and Epitaxy within the semiconductor production value chain**, illustrating that these technologies are both forms of **chemical vapor deposition, which forms one of the critical iterative steps within front-end wafer manufacturing.** We highlight that **single-wafer ALD and Epitaxy play a key role in the production of the most complex and capital-intensive layers** of the chip.

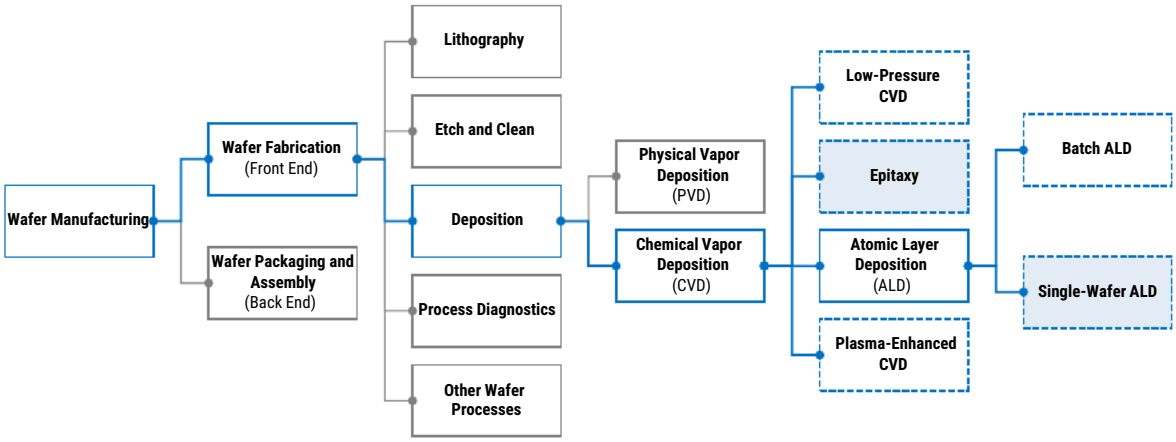
Exhibit 7: Single-wafer ALD and Epitaxy tools are used for front-end-of-line deposition, where there is the highest concentration of capex-intensive critical chip layers
Overview of Front-End-of-Line vs. Back-End-of-Line Layers

Front-End-of-Line vs. **Back-End-of-Line** Layers

Layer Type	Commentary	Deposition Technology
Front-End-of-Line (FEOL)	• In FEOL layers, critical **individual components** (such as, transistors, capacitors, and resistors) **are patterned onto the wafer** and we believe they require the **highest materials expertise** • These are the **only active layers** on the silicon substrate	**ALD / Epitaxy**
Back-End-of-Line (BEOL)	• In BEOL layers, electronic **components are connected using metal interconnects** in order to distribute signals. • **Local interconnects** (close to transistors) need to be **small and densely packed**, while **global interconnects** (travel across circuit) **are thicker** to minimize resistance • Interconnect **levels are connected by metal "vias"**, which can be made from aluminum, or more recently, copper	**Physical Vapor Deposition**

Source: Goldman Sachs Global Investment Research

Exhibit 8: Single-wafer ALD and Epitaxy are types of Chemical vapor Deposition, and one of the key steps in the iterative (deposition/lithograph/etch) process of chip making
Wafer Manufacturing Industry Map



Source: Goldman Sachs Global Investment Research

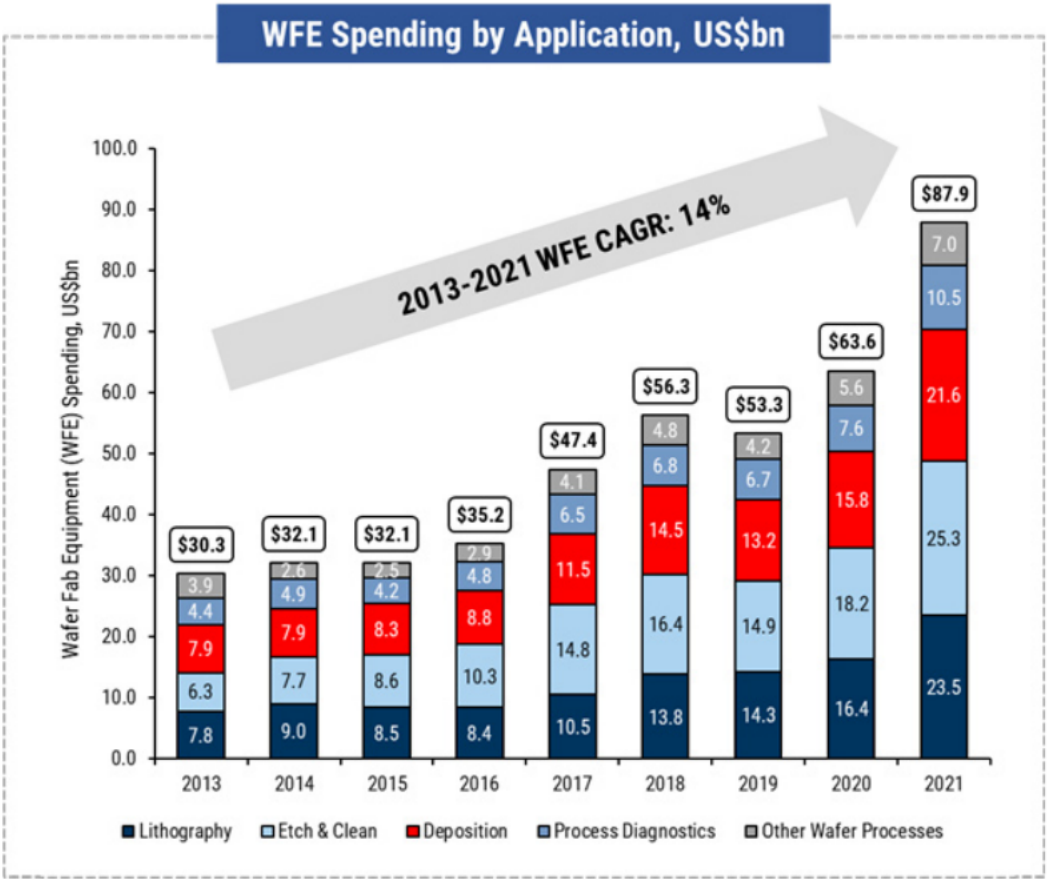
We expect growth in single-wafer ALD and Epitaxy to outpace traditional deposition technologies in coming years, given their role in driving increased transistor performance

While the broader deposition market has grown at a 13% 2013-21 CAGR, broadly in line with that of the underlying WFE market, we expect growth in single-wafer ALD and Epitaxy to outpace traditional deposition technologies in coming years, driven by the increased intensity of advanced deposition techniques used at the leading-edge nodes. As such, we see robust double-digit growth on a multi-year basis.

- We see the overall deposition market being broadly characterised into two key techniques: **1) physical vapor deposition (PVD), and 2) chemical vapor deposition (CVD).** As detailed in the exhibit below, **PVD is a deposition method whereby thin films are deposited via the transfer of particles from a solid target** of precursor material onto the wafer. We see this as a less technologically complex approach that is typically used to **deposit materials including aluminium and copper to fabricate BEOL layers** in the chip (i.e. wiring).
- Conversely, **CVD is an alternative to PVD that forms thin films on the wafer through a series of chemical reactions that typically leverage *gaseous* precursors**, rather than solid ones. As compared to PVD, CVD offers **improved uniformity**, and can be used to deposit a greater variety of materials with a higher degree of precision.
- However, the key drawback of *traditional* CVD processes is that **precursors, by-products, and other molecular fragments all float around in the reaction chamber together, which can leave uneven films on the surface of the wafer.** As discussed in greater detail below, **Atomic Later Deposition and Epitaxy are special *types* of CVD that are increasingly used for critical layers at leading-edge technology nodes** in order to allow for **finer *control* over the**

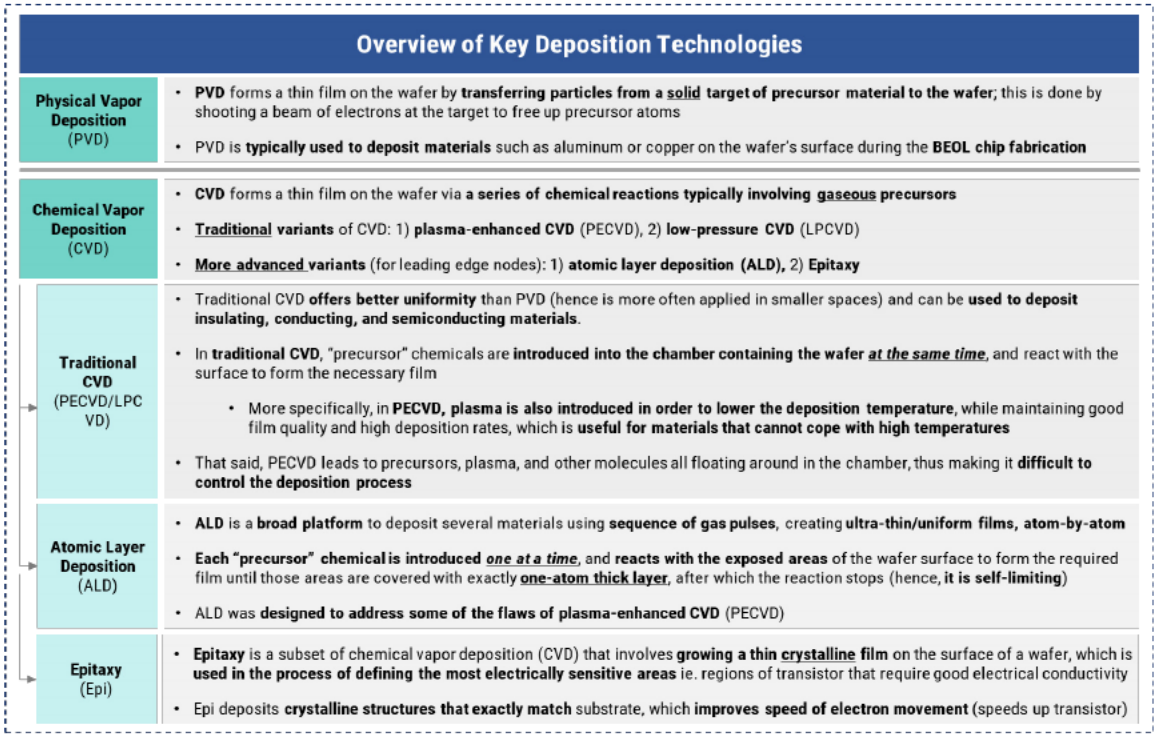
thickness and shape of the deposited material to ultimately *improve transistor performance,* positioning these technologies as **key Digital Enablers**, in our view.

Exhibit 9: The deposition market grew at a 13% CAGR (2013-21), broadly in line with WFE spending
WFE spending by application, US$bn



Source: ASM International, Goldman Sachs Global Investment Research

Exhibit 10: Key deposition techniques include Physical Vapor Deposition (PVD), Chemical Vapor Deposition (CVD), and Atomic Layer Deposition (ALD) and Epitaxy



Source: Goldman Sachs Global Investment Research

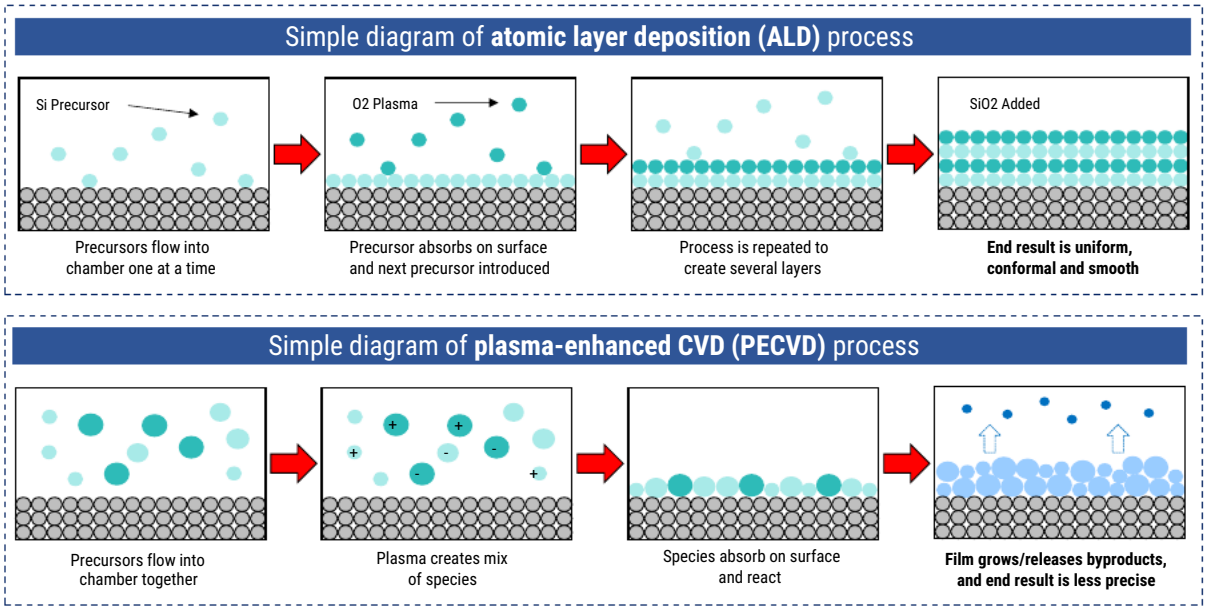
ALD to grow at 20% CAGR as it allows depositing of ultra thin and uniform films of material one atomic layer at a time, thus achieving a high degree of control and ultimately helping improve transistor performance

- **Atomic Later Deposition is a special class of CVD**, used for depositing **ultra-thin and uniform films *one atomic layer at a time*** in the most **critical layers of leading-edge technology nodes,** making it the **most advanced deposition method available today.** Layers are formed by exposing the wafer to a sequence of **pulses of gaseous precursors,** with by-products purged out in between each pulse, which allows for a **finer control over the thickness and shape of the deposited material.** This can be achieved either temporally, where the wafer stays still, or spatially, where the wafer moves across different zones.
- As shown in Exhibit 11, each **precursor chemical is introduced one at a time**, and **reacts with the exposed areas of the wafer surface to form the required film** until those areas are covered, after which the reaction stops. Therefore, the **ALD process is self-limiting**, given that once a given precursor has entirely reacted with the exposed areas of the wafer surface, the **reaction ceases automatically, resulting in films with uniform thickness**, even over varying surface topographies (i.e. not flat surfaces). By introducing one material into the chamber at a time, **ALD avoids the "soupy" nature of legacy CVD** (which introduces several gases into the chamber at once), and thus **leaves higher-quality thin films.**
- We see these **precision advantages manifesting into higher levels of uniformity**

(how controlled the thickness of the deposited material is across the wafer), **conformality** (the extent to which layers of deposited material adhere to the shapes and crevices of the underlying wafer's surface) and **smoothness** (the degree to which the deposited layers are atomically smooth) within the chip structure, which ultimately **improve transistor performance.**

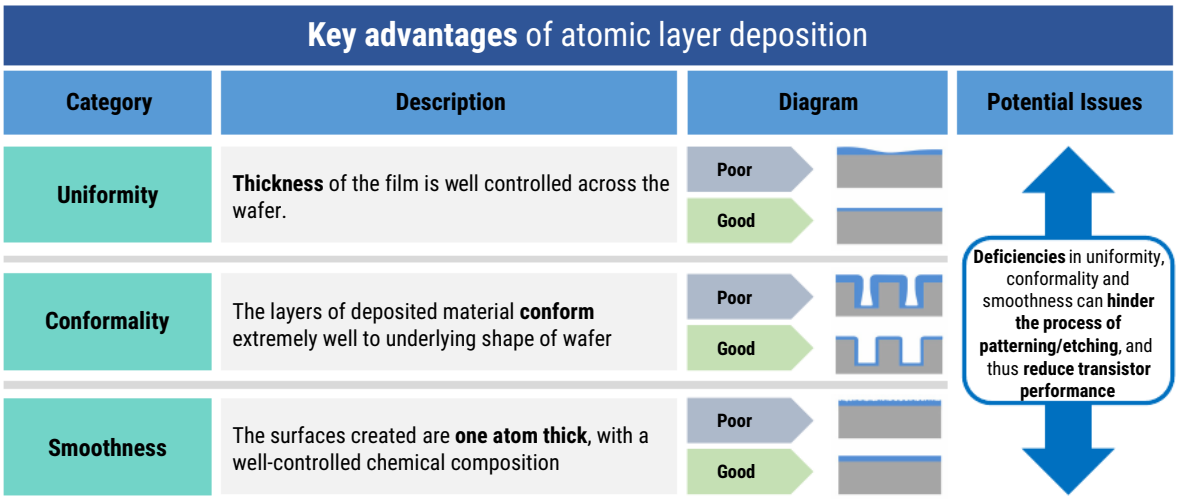
As illustrated below, deficiencies in uniformity, conformality and smoothness can hinder the process of patterning/etching and hence reduce transistor performance, thus necessitating ALD usage at the most advanced nodes.

Exhibit 11: ALD achieves higher precision by introducing reactant chemicals individually, whereas PECVD involves lower degree of control, since chemicals are introduced together



Source: Goldman Sachs Global Investment Research, Lam Research

Exhibit 12: Single-Wafer ALD maximises precision, crucial for leading-edge nodes



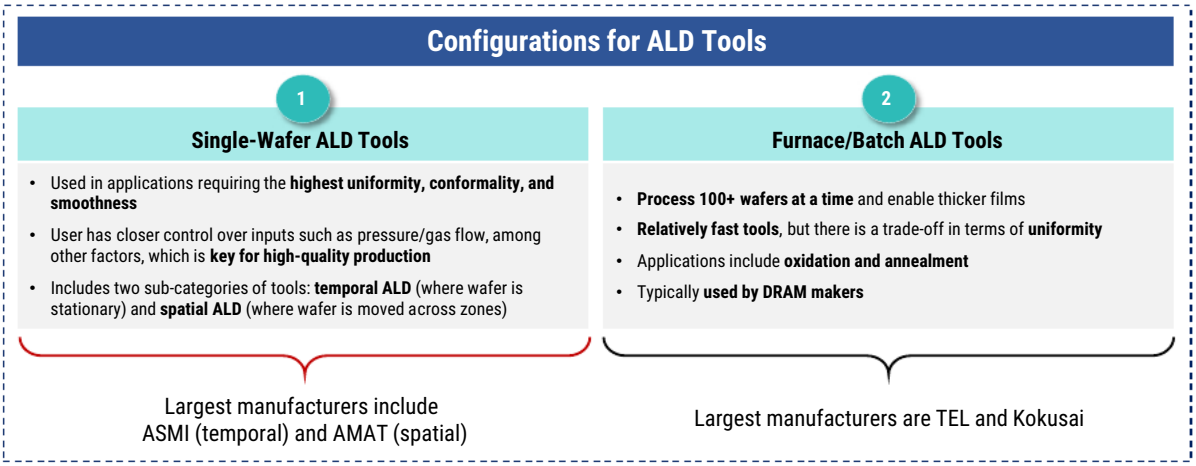
Source: Goldman Sachs Global Investment Research, Lam Research

More specifically, we note that there are a variety of single-wafer ALD and batch/furnace ALD tools offered by deposition semicap players.

- **Single-wafer ALD tools are used in applications with the highest requirements for uniformity, conformality and smoothness,** and focus on precision rather than throughput by depositing on only a few wafers at a time. This enables **closer control over inputs such as pressure/gas flow**, among other factors, which are **critical for the production of high-quality chip structures**, particularly at the leading-edge nodes.
- Conversely, **batch/furnace ALD tools are able to process 100+ wafers simultaneously** (i.e. high throughput) but have a **trade-off in terms of precision**. We believe that **batch ALD tools are often more appropriate to use in applications with thicker films**, where **single-wafer ALD could be an uneconomical** approach. For example, we note that batch ALD usage is relatively more common among DRAM manufacturers.
- We note that the largest manufacturers of furnace/batch ALD tools today are Tokyo Electron and Kokusai. While **ASM International maintains a niche position in batch ALD** (e.g. selectively investing in analog market applications), it is the **market leader (c55% share) in single-wafer ALD tools**, alongside **Applied Materials, which also has a relatively strong position.**

Exhibit 13: ALD is divided into 1) single-wafer ALD, for applications requiring the highest precision, and 2) Furnace/Batch ALD tools, which prioritise throughput

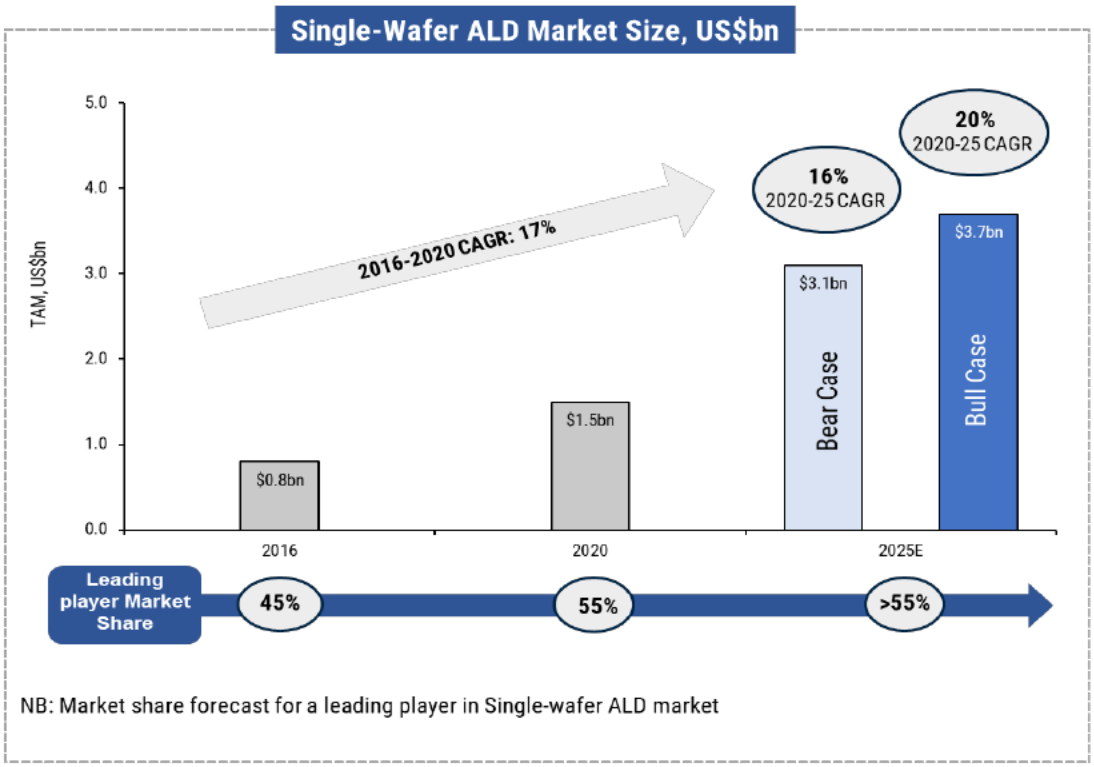
Key configurations for ALD tools



Source: Compiled by Goldman Sachs Global Investment Research

While the **single-wafer ALD market was around $1.5bn in 2020** (c9% of the broader deposition market), we note that ASMI, a key player in the single-wafer ALD market, **expects the market to more than double in coming years** and **forecasts a 20% 2020-25 market CAGR to $3.7bn in 2025 in a blue-sky scenario.**

Exhibit 14: Single-wafer ALD market growth is expected to accelerate and, according to ASMI, reach up to $3.7bn by 2025 vs. $1.5bn in 2020 in a blue-sky scenario



Source: ASM International, Goldman Sachs Global Investment Research

Epitaxy is a deposition process (similar to ALD) for crystalline substances in the most electrically sensitive areas, helping improve speed of electron movement, and we expect the market to grow at a double-digit CAGR

Epitaxy (Epi) is another special class of chemical vapor deposition (CVD), and is a process for depositing highly controlled, thin, silicon-based *crystalline* films that are important for the electrical properties of semiconductor devices such as transistors (the brain cells of the chip). We see Epitaxy as a similar, albeit more niche, application of ALD, and as such, conceptualise these as separate, but similar types of chemical vapor deposition.

- By using **Epi to deposit crystalline structures that exactly match the underlying substrate**, chip makers are able to **improve the electrical properties of the chip**, such as the speed of electron movement, which enhances (i.e. speeds up) transistor performance. It is especially appropriate for defining the most electrically sensitive areas i.e. regions of the transistor that require good electrical conductivity. We expect **Epi to play a key role in the transition to Gate-All-Around transistor architectures**, which will require **more uniform deposition on increasingly complex structures.**
- While **historically Applied Materials was a dominant player in advanced Epitaxy applications**, we note that **ASMI's introduction of the Intrepid ES tool in 2017 to enter the leading-edge Epi market** (with ASMI having historically focused on Epi for legacy analog/power markets) has **somewhat allowed it to gain market share, in our view.**
- While **ASMI was selected for some Epitaxy applications at a leading Foundry player in 2017**, we note that the company has also recently won a **second key customer for advanced Epi tools with Gate-All-Around applications**, which we believe demonstrates the suitability of this technology for the upcoming transistor architecture transition. As such, **ASMI's Epi market share expanded from 5% in 2016 to 15% in 2020**, with the company targeting **over 30% share by 2025**, as shown in Exhibit 16.

Exhibit 15: Epitaxy is a deposition process (similar to ALD) for crystalline substances in the most electrically sensitive areas of semiconductors

Overview of Epitaxy

Epitaxy	
What is Epitaxy?	• **Epitaxy** is a type of chemical vapor deposition (CVD) that **grows thin crystalline films** on a wafer • Used to **define the most electrically sensitive areas** i.e. regions of transistor that require good electrical conductivity

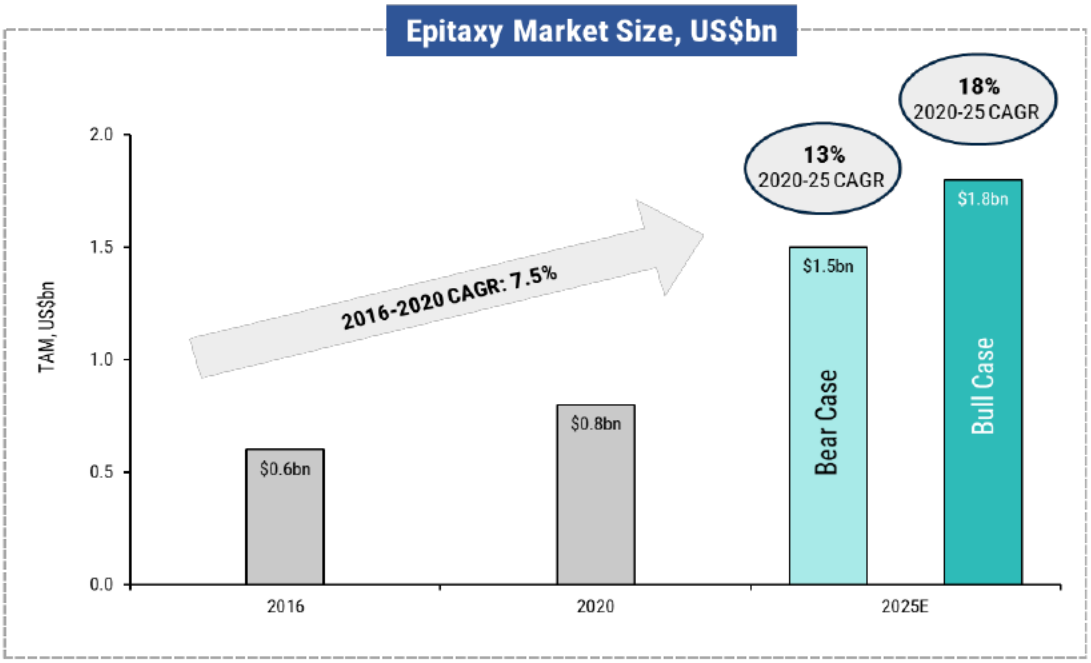
Benefits of Epitaxy?	• Depositing **crystalline structures that exactly match substrate improves speed of electron movement** (speeds up transistor)
	• **Epitaxy also helps minimize electron leakage**, which can be a drawback at small nodes
	  • **As chips continue to shrink, so do the spaces between electrical components**, such as transistors
	  • This causes current to **leak between components**, which **hinders performance and increases power consumption**

Key Customer Wins	• **ASMI historically specialized in Epitaxy for power markets**, which is a niche sub-segment of the broader Epitaxy market • In the past, AMAT maintained a monopoly in advanced Epitaxy, but **ASMI introduced the *Intrepid ES* tool in 2017 to enter the Epitaxy market for leading-edge applications** (e.g. sub-7nm Logic) • **ASMI's Intrepid ES was selected by a leading foundry customer for an Epi layer at the 7nm node, and in 2019 for multiple layers at the 5nm node** • Recently, **ASMI have announced a second customer for its Epitaxy tools**, which we believe demonstrates the **suitability of the technology for the upcoming GAA transition**
Use Cases	• Epitaxy helps deposit **thin films with atomic structures *exactly matching* the structure of the underlying wafer**, which helps **improve the electrical properties of the chips** • We expect Epitaxy to play a **key role** in this regard during the **transition to gate-all-around** • This is known as **homoepitaxy**, and will be leveraged to build the **channel, source and drain of transistors**

Source: Company data, Goldman Sachs Global Investment Research

Exhibit 16: While the Epitaxy market is smaller than single-wafer ALD, ASMI expects it to grow at a strong double-digit CAGR on a multi-year basis

ASMI expects the Epitaxy market to reach US$1.5bn to US$1.8bn by 2025



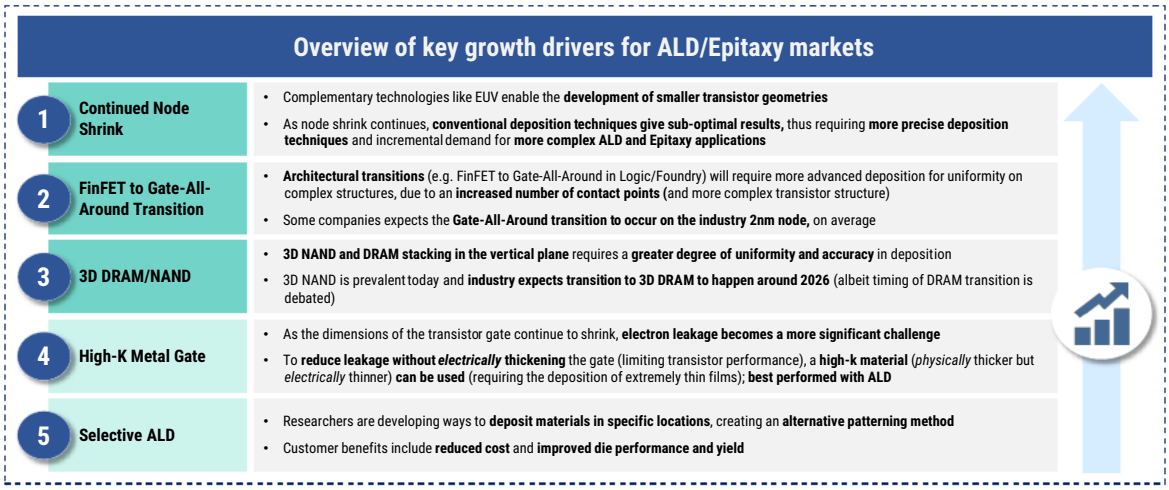
Source: Company data, Goldman Sachs Global Investment Research

Atomic Layer Deposition/Epitaxy market growth will be driven by continued node

shrinkage and more complex transistor designs in Logic and Memory, including Gate-All-Around (and 3D DRAM)

We see multiple compelling growth drivers for the single-wafer ALD and Epitaxy markets, including **1) EUV-enabled node *shrink* requiring high-precision deposition, which catalyses incremental ALD demand, 2) Structurally higher demand for advanced deposition techniques (e.g. ALD/Epi) catalysed by the upcoming Gate-All-Around transistor design shift, and 3) Growing importance of high-k materials at smaller nodes, which are best deposited with ALD. While we remain cautious that the benefits related to 4) the transition to 3D DRAM could take longer than expected to be seen, we see scope for these to be a driver longer term and also highlight tailwinds from key pillars of the ongoing trend of Digitalisation such as 5G, Automated Driving Tech, and IoT, driving continued growth in the advanced semis market, underpinning our expectation for a robust multi-year CAGR for advanced deposition equipment spending.**

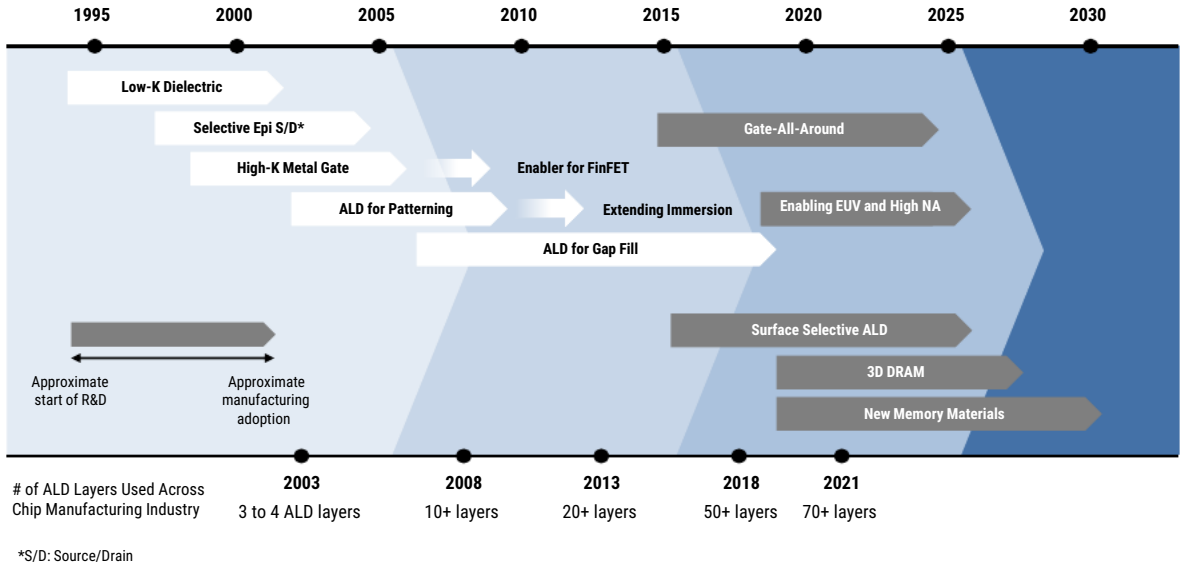
Exhibit 17: We are most bullish on the transition from FinFET to Gate-All-Around and continued leading-edge node shrinkage as drivers of ALD/Epi demand, and see 3D DRAM as a longer-term driver
Overview of ALD/Epitaxy market growth drivers



Source: Goldman Sachs Global Investment Research

Exhibit 18: We see ALD/Epitaxy benefiting from upcoming tech inflection points such as Gate-All-Around; timing of 3D DRAM appears further out in time

Key technological inflection points



Source: Company data, Goldman Sachs Global Investment Research

We expect that as leading-edge node shrink continues (partially enabled by complementary technologies such as Extreme Ultraviolet Lithography (EUV)), traditional deposition techniques such as physical/chemical vapor deposition will provide sub-optimal results, thus requiring greater uptake of more *precise* technologies such as single-wafer ALD and Epitaxy.

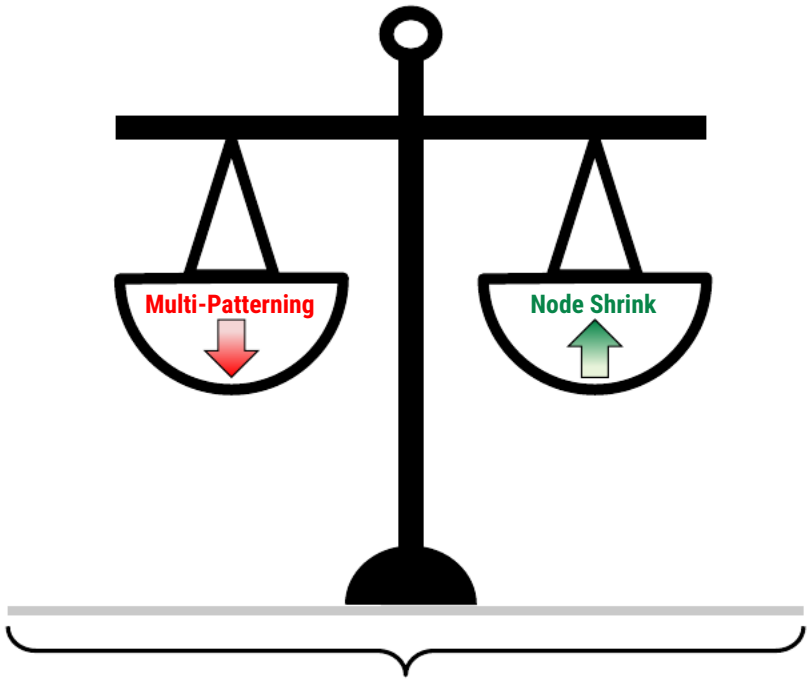
- In recent years, as **EUV replaced more traditional lithography technologies such as DUV**, lowering the need for multiple pass patterning (i.e. exposure of the wafer multiple times to allow for a sharp image), ALD saw a **decrease in demand for patterning-relating applications** (e.g. deposition of spacers).
- However, **EUV has also enabled (and will increasingly enable) the development of *smaller transistor geometries*** at which **conventional deposition methods are not able to meet some of the higher precision requirements** (due to ***smaller dimensions***), thus catalysing greater uptake (especially as progressions to smaller nodes proceed) of more complex technologies such as **single-wafer ALD and Epitaxy that are able to deposit thin films one atomic layer at a time.**
- As such, **we expect the single-wafer ALD market to experience a net strong *benefit* from continued node shrinkage** and see supporting evidence in the fact that the **Foundry transition to N5 (industry 7nm), which was the first major insertion of EUV, led to a strong *positive* inflection of single-wafer ALD applications**. Overall, we expect EUV-enabled node shrink to be a strong driver in the medium term and note that key ALD player **ASMI has secured multiple new (double-digit % increase) ALD layers and applications for the next node transition** (which is expected to ramp into **high volume manufacturing in 2H22/2023).**

Exhibit 19: EUV-enabled node shrink requires high-precision deposition, which catalyses incremental ALD demand, despite cannibalising the MPP-related ALD opportunity

1	As node shrink continues, conventional deposition techniques give sub-optimal results
What is happening?	• ALD has benefited from **demand due to multi-pass patterning** (MPP), such as through the deposition of spacers • Complementary technologies like EUV enable the **development of smaller transistor geometries** • As node shrink continues, **conventional deposition techniques run out of steam, thus catalysing incremental demand for novel ALD and Epitaxy applications** (which replaces MPP layers that may be potentially cannibalized by EUV)
What is the market opportunity?	• Continued scaling towards smaller devices such as Fork-Sheet (i.e. second-generation) gate-all-around places **higher demands on conformality, uniformity and smoothness of deposited materials** • The combination of **thinner films and new materials is best addressed using ALD and Epitaxy, thus reducing the need for multiple pass patterning steps, each of which requires deposition** • While **EUV insertion cannibalizes ASMI's multi-patterning business**, this effect is **offset by novel ALD/Epitaxy applications due to node shrink enabled by EUV**, and is ultimately a growth driver for the company • One proof-point of this dynamic is the Foundry transition to N5 (industry 7nm), where the **first major insertion of EUV coincided with a strong inflection in ALD applications**
Short-term vs long-term?	• We expect **continued node shrink to be a near-term driver,** catalysing **growth in number of ALD layers in 2023/24**

Source: Company data, Goldman Sachs Global Investment Research

Exhibit 20: We see scope for new ALD layers driven by EUV-enabled node shrink to offset the cannibalisation of MPP-related ALD in the medium term



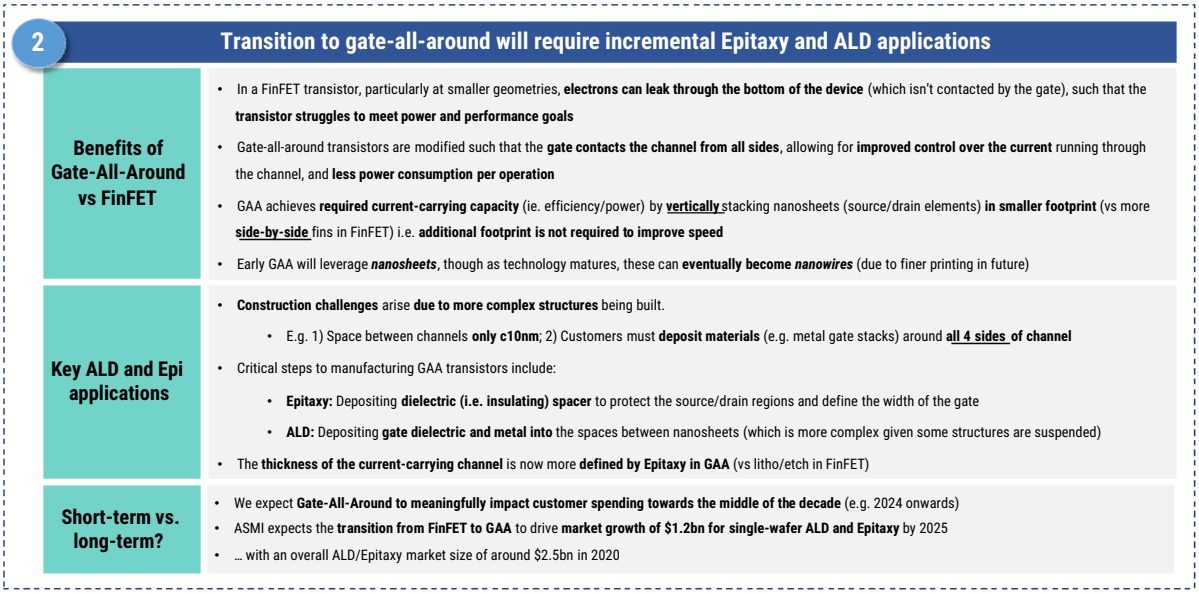
Source: Goldman Sachs Global Investment Research

Further, we believe that the transition to Gate-All-Around transistor architectures will be a significant inflection point for the single-wafer ALD and Epitaxy markets,

given our view that significantly more emphasis will be placed on Epi to build up the transistor channel, along with incremental ALD applications to construct the transistor gate.

- In a FinFET transistor, particularly at smaller geometries, **electrons can leak through the bottom of the device** (which isn't contacted by the gate), such that the **transistor struggles to meet higher power and performance goals.**
  - **Gate-All-Around transistors are modified such that the gate contacts the channel from all sides**, allowing for **improved *control* over the current running through the channel,** and **less power consumption** per operation.
  - As such, **Gate-All-Around improves efficiency by virtue of being able to achieve the same current-carrying capacity by *vertically* stacking nanosheets in a smaller footprint** (vs more side-by-side fins in FinFET), i.e. additional footprint is not required to improve transistor performance because you can expand vertically rather than horizontally. As explained below, this will lead to increased need for both Epitaxy and ALD given the structures involved.

Exhibit 21: Transition to Gate-All-Around will require significantly more Epitaxy to build up the transistor channel, along with incremental ALD applications to construct the transistor gate



Source: Company data, Goldman Sachs Global Investment Research

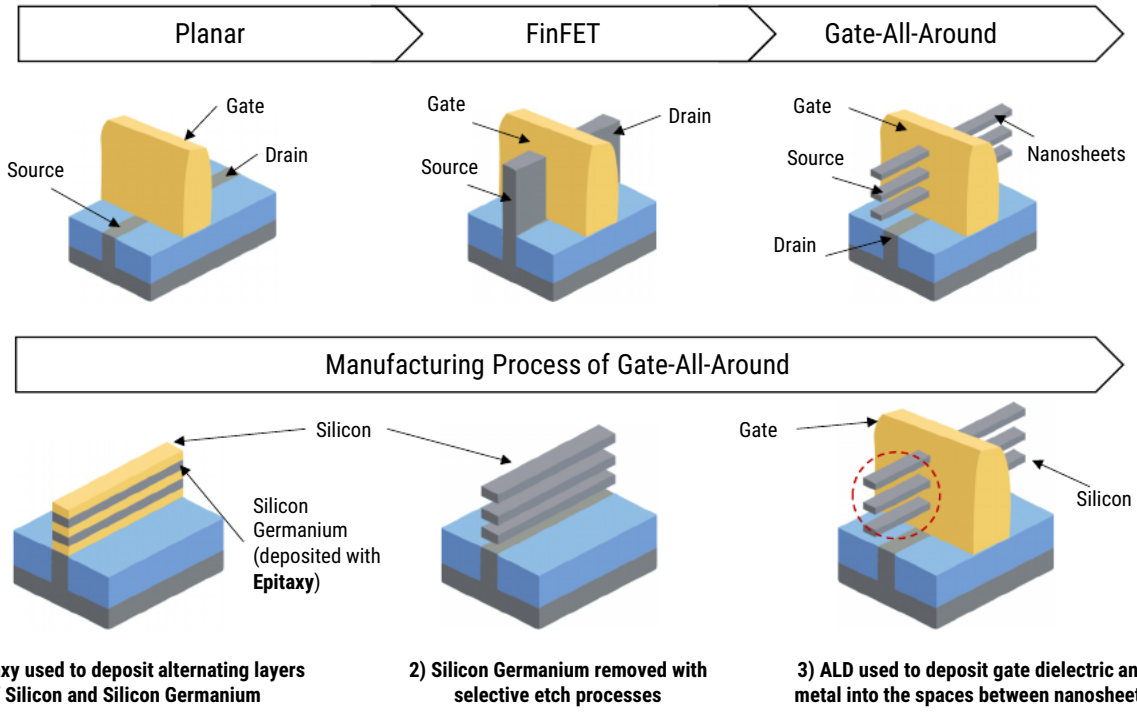
We expect that a number of key construction challenges will arise with Gate-All-Around transistors that are easier to overcome with the use of ALD and Epi.

- Gate-All-Around requires far more *precise* deposition techniques given that 1) the **space between the vertical channels is only around 10nm** and 2) chip makers must **deposit materials (e.g. metal gate stacks) around all 4 sides of the channel,** as shown in Exhibit 23, including **difficult to access regions in-between suspended vertical channels**.
- We note that some of the most **critical steps to Gate-All-Around will require**

Epitaxy, such as to deposit dielectric (i.e. insulating) spacer to **protect the source/drain regions** (i.e. creating the alternating layers of material to build up the source/drain and channel regions, which are nanosheets). Therefore, in the new Gate-All-Around design, the **thickness of the current-carrying channel is defined by Epitaxy** (as opposed to being defined by litho/etch in FinFET transistors).

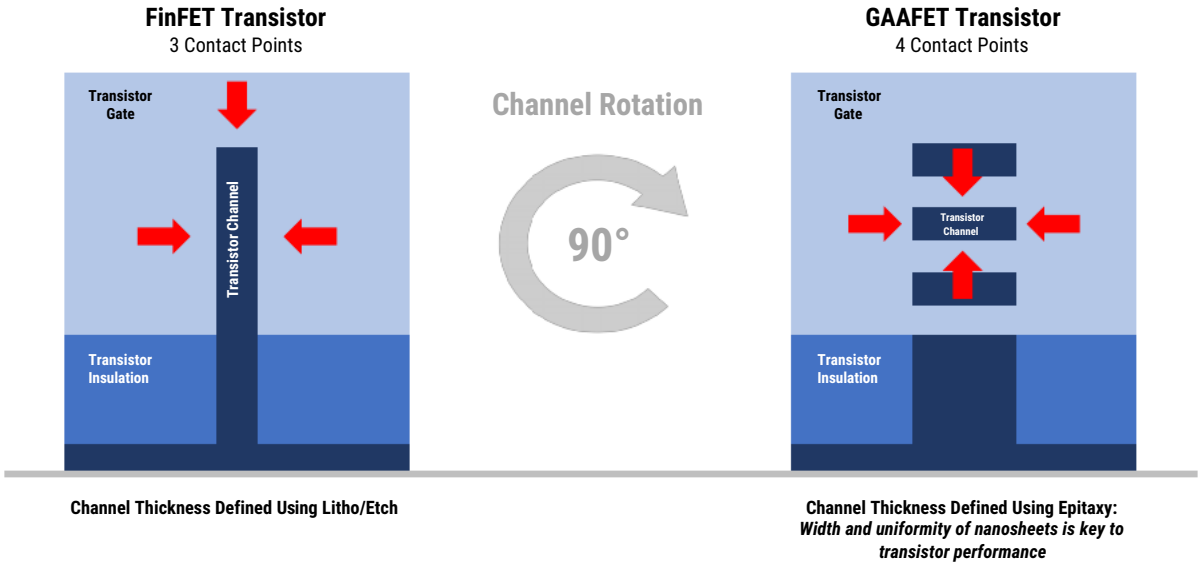
- Moreover, **ALD is required to deposit gate dielectric and metal into the spaces *between* nanosheets,** which is more complex given that some structures are ***suspended*** **in the new Gate-All-Around design,** as shown in the exhibits below. As such, we see scope for the Gate-All-Around transition to be a **meaningful revenue driver in the medium term (e.g. 2024 onwards)**, and note that key ALD player ASMI expects the **new Gate-All-Around structure to drive incremental TAM growth of $1.2bn by 2025. We see this as a significant growth opportunity for the industry given that the overall market size for ALD and Epitaxy was around $2.5bn in 2020.**

Exhibit 22: Gate-All-Around involves a more complex manufacturing process that requires more precise deposition techniques
Illustrative comparison of planar vs FinFET vs Gate-All-Around transistors



Source: Goldman Sachs Global Investment Research

Exhibit 23: Epitaxy defines the thickness of the transistor channel in a Gate-All-Around (GAA) transistor, whereas current-gen FinFET transistors depend on Litho/Etch to a greater degree



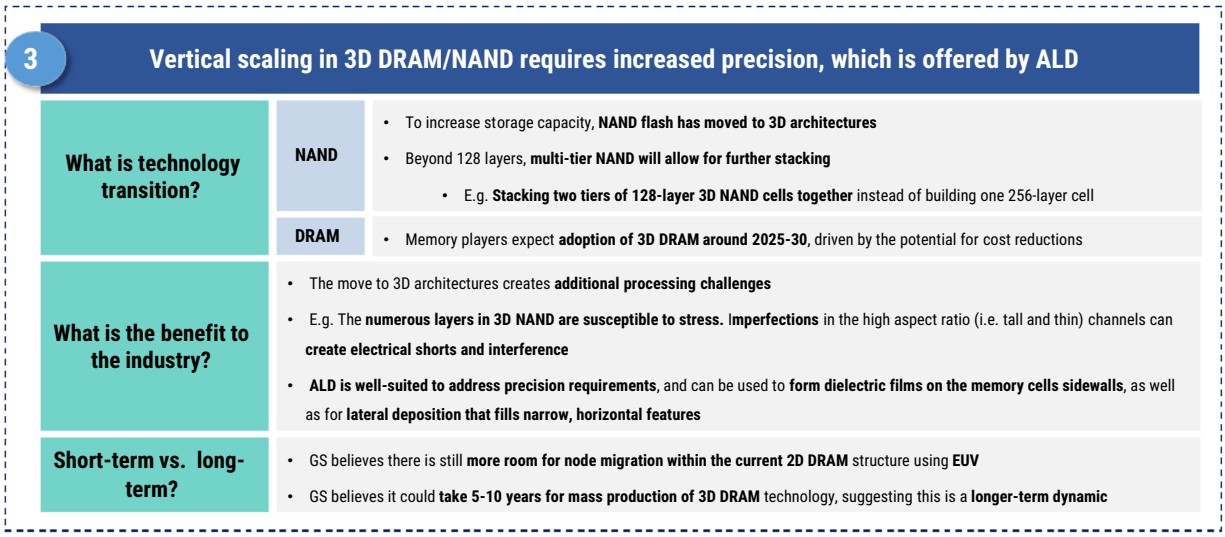
Gate-All-Around is a new transistor architecture where the gate contacts the channel from all sides, enabling better performance

Source: Goldman Sachs Global Investment Research

We also believe that vertical scaling of 3D structures in DRAM and NAND Memory is likely to drive an increased market opportunity for ALD. That said, while 3D NAND has been successfully commercialised, we remain cautious on the likelihood of a near/mid-term transition to 3D DRAM structures, noting mixed commentary from key Memory players, and expect this to be a longer-term dynamic.

- In NAND, **Memory players are looking to further stack memory cells higher into vertical layers to enable greater storage capabilities in a smaller footprint**, as well as shorter overall connections for each memory cell, which **supports faster memory performance.**
- However, these **taller structures create additional processing challenges,** as the numerous layers have ***very high aspect ratios*** (i.e. very tall, very thin), which are ***susceptible to stress*** **and imperfections** that can create electrical shorts and interference. **Atomic Layer Deposition is well-suited to the precise deposition requirements in these structures**, given its ability to form **very thin films in the memory cell sidewalls, as well as deposition into the narrow horizontal features.**
- That said, we still see more **room for node migration within the current 2D DRAM structure** using EUV and believe it could take **5-10 years for mass production of 3D DRAM**, suggesting that incremental growth for the ALD/Epi markets from 3D stacking could be a **longer-term dynamic.**

Exhibit 24: Vertical scaling in 3D DRAM/NAND can produce high-aspect-ratio structures whose deposition requires the increased precision offered by ALD



Source: Company data, Goldman Sachs Global Investment Research

We highlight that while high-k materials, which are best deposited with ALD, are an established technology that has been in mass production for several years, we see new high-k applications (as transistor dimensions continue to shrink) supporting the longevity of this market growth driver.

- As the **dimensions of the transistor gate continue to shrink, electron leakage becomes a more significant challenge.** To reduce leakage, chip makers want to ***physically*** **thicken the gate without increasing its** ***electrical*** **thickness** (otherwise it would be more difficult for electrons to flow, limiting transistor performance).
- A **high-k material** can be used, as this is ***physically*** **thicker without being** ***electrically*** **thicker**. This requires the deposition of **extremely thin films, which is best performed with ALD.**
- While **high-k metal gates are already a key enabling technology for the FinFET architecture** (which some companies plan to continue scaling for the next 3-4 years), we also see this technology **playing a role in the transition to Gate-All-Around**. Further, certain companies such as ASMI expect that the migration of the DRAM periphery to high-k dielectric and metal gate will significantly reduce power consumption (in a manner similar to logic devices). As such, we expect this **mature growth driver to drive new ALD applications in both the near and longer term.**

Exhibit 25: High-k materials help reduce electron leakage and will become increasingly important at smaller nodes; these are best deposited with ALD

4	High-k materials, which provide better insulation, are best deposited with ALD
What is driving adoption of high-k materials?	• As the dimensions of the transistor gate continue to shrink, **electron leakage becomes a more significant challenge** • To reduce leakage, chip-makers want to ***physically*** **thicken the gate without increasing its *electrical* thickness** (otherwise it would be more difficult for electrons to flow, limiting transistor performance) • A **high-k material can be used**, as this is *physically* thicker without being *electrically* thicker • This requires the deposition of extremely thin films, **which is best performed with ALD**
What are the key applications?	• **High-k metal gates are a key enabling technology for FinFET** architecture, (which we believe will also allow for further scaling), **as well as playing a role in the transition to gate-all-around** • **Adoption of high-k materials in DRAM in order to scale the peripheral transistors** (due to better power efficiency and performance) in the memory cell is a robust driver of ALD, due to high precision requirements
Short-term vs long-term?	• While **high-k materials are an established** technology, we see **new applications driving growth over the near and long-term**.

Source: Company data, Goldman Sachs Global Investment Research

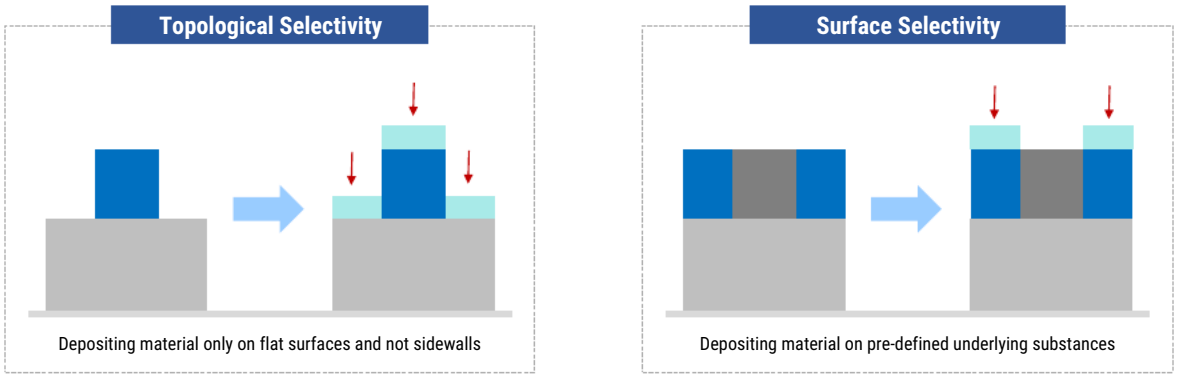
Lastly, we note early-stage research into selective ALD (i.e. depositing materials in specific locations), which could potentially lead to reduced costs for customers given the possibility to eliminate certain litho-etch steps, as shown in the exhibits below. That said, we see this growth driver as a long-term blue-sky scenario and believe that any potential impacts are likely to only become more meaningful beyond 2025+.

Exhibit 26: Selective ALD could lead to reduced costs, along with potentially improved die performance and yield, in the longer term

5	Selective ALD could lead to reduced costs, along with improved die performance and yield
What is happening?	• Researchers are developing ways to **deposit materials in specific locations**, essentially creating an **alternative patterning method** • Key benefits to customers from replacing certain litho-etch steps with selective ALD can include **reduced cost** (due to fewer steps), **improved die performance and yield**
What is the market opportunity?	• **Topological selectivity** involves **depositing material on flat surfaces** (as opposed to side walls) • **Surface selectivity** involves **depositing extra material** on certain, pre-determined types of underlying material • There is currently a method of **topo-selective ALD in production** (used in 3D NAND) **that leverages silicon nitride** • ASMI sees technologies related to **surface-selective ALD** (driven by Logic/Foundry) **occurring during the adoption of the 2nm node**
Short-term vs long-term?	• Selective ALD technology is still in **early-stages**, with any potential impacts likely to **only become more meaningful beyond 2025+**

Source: Company data, Goldman Sachs Global Investment Research

Exhibit 27: Top-down (litho-etch) processes could be supplemented with bottom-up (selective ALD) technologies to improve process efficiency
Types of selective ALD



Source: Company data, Goldman Sachs Global Investment Research

ASMI is the largest player within ALD whereas AMAT is the biggest within Epitaxy

Single-wafer ALD and Epitaxy are **smaller/niche segments** of the **overall WFE market today**, with market sizes of around **$1.5bn/$0.8bn** respectively. That said, we expect these markets to **grow at 20%/18% CAGRs across 2020-25**, driven by **leading-edge node shrinkage** and **transitions towards a more complex architecture** in logic/memory applications, e.g. **Gate-All-Around, 3D DRAM**.

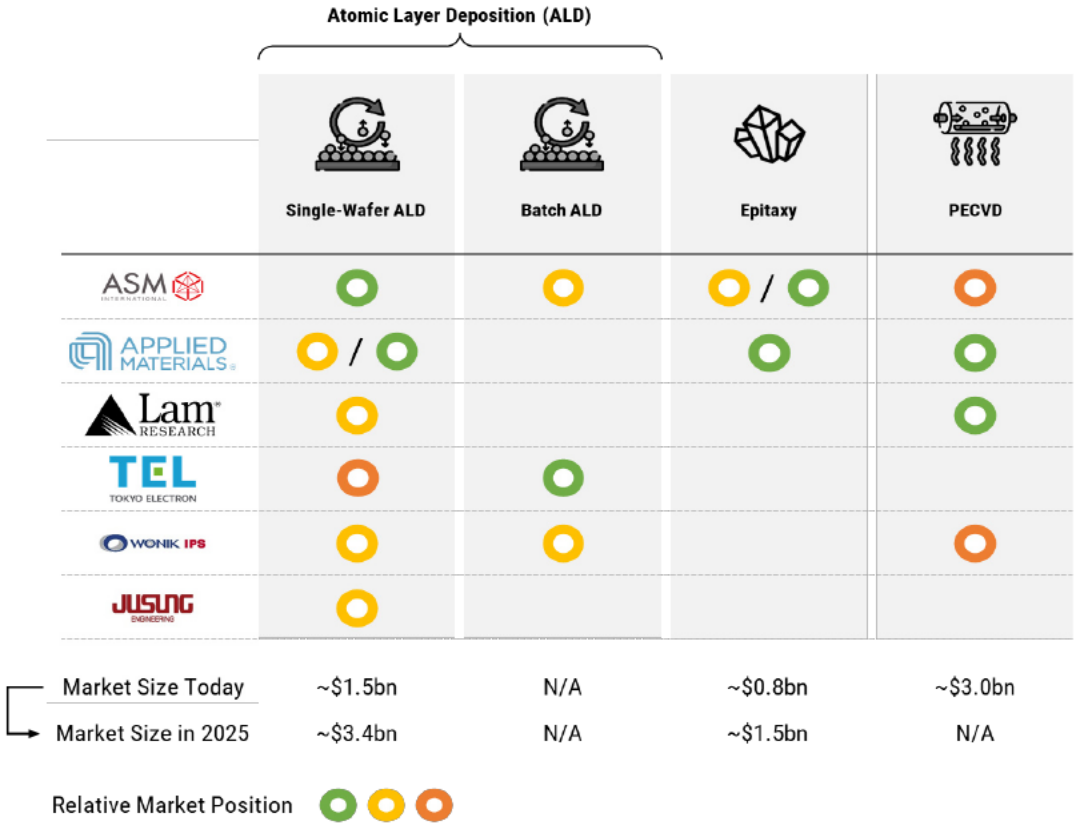
Key suppliers of the single-wafer ALD equipment include **ASMI** (***world leader in single-wafer ALD with a 55% market share***), with around 3-4x revenue vs. its closest competitor. **ASMI** has a **strong position in the logic/foundry segment** with **a leading IDM player** being one of its **key customers**. The market is **more fragmented** in the **memory ALD market segment**, with **Lam Research and TEL having meaningful positions in specific applications.** ASMI has a growing market share in memory but faces some headwinds due to presence of other companies.

In the **Epitaxy market, we see AMAT as the historical market leader**, with **ASMI** breaking into this market with an **initial market share of 5% in 2015 and then grew to 15% in 2020**. ASMI is seeing **increasing traction** for its products in **advanced CMOS and power/analog** (and ***targets to expand to >30% by 2025***) driven by new customer wins for advanced Epitaxy tools.

Established players like **AMAT and LAM Research have a strong market position In the physical vapor deposition market**, which is more heavily used in more traditional applications, e.g. copper wiring chips.

Lastly, in **Batch ALD**, a form of ALD focused on higher productivity (at the sacrificing of higher precision), Tokyo Electron and Kokusai are the market leaders.

Exhibit 28: Key players in the ALD market are ASMI, Applied Materials and Lam Research
Equipment suppliers in the ALD, Epitaxy and PECVD end markets



Market estimates from ASM International

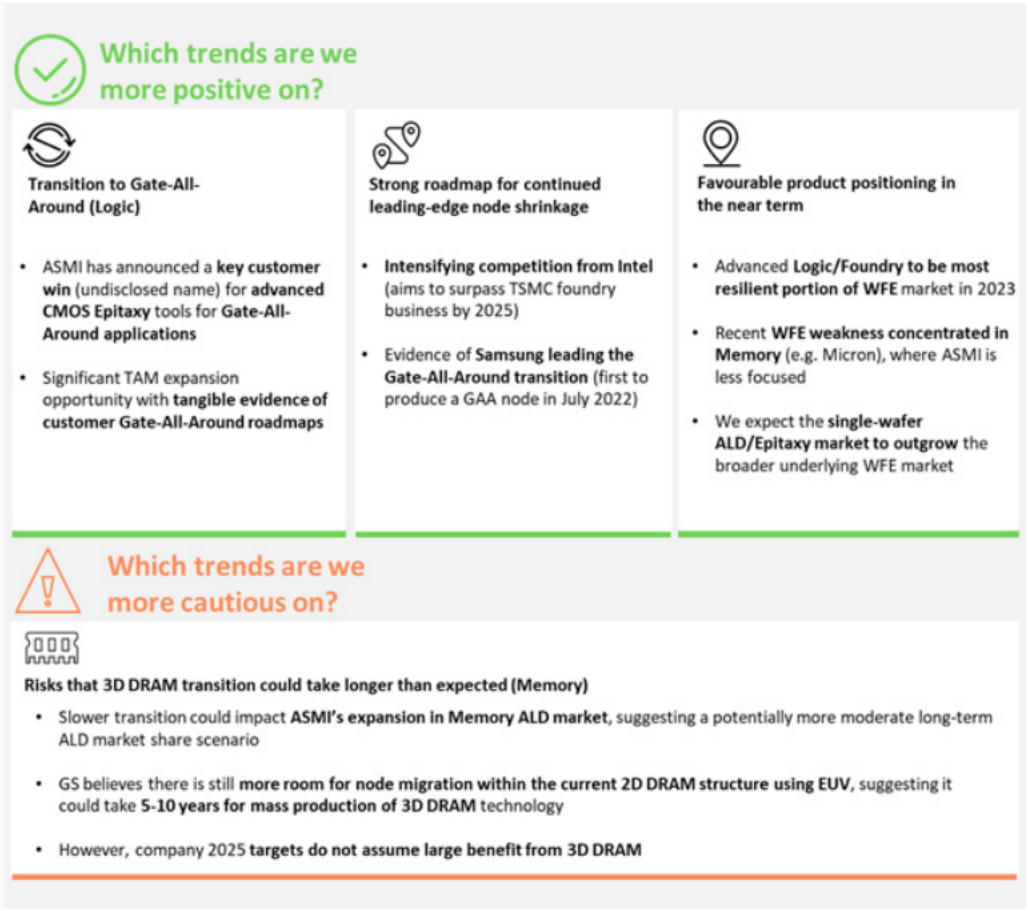
Source: ASM International, Goldman Sachs Global Investment Research

Initiate on ASMI with a Buy rating; Digital Enabler benefiting from leading-edge chip transitions

We initiate on ASM International (ASMI), the market leader in single-wafer Atomic Layer Deposition (ALD) equipment, with a Buy rating and a 12-month price target of €365, which implies 51% upside (based on 03 Oct close). Our rating is predicated on a more constructive view than implied by consensus on growth drivers such as the transition to Gate-All-Around transistor structures, continued node shrink at leading Logic/Foundry players, and favourable end-market exposure relative to other semicap players. Given our view that the company will remain well positioned in ALD/Epitaxy and thus play a key role in helping facilitate cost-effective growth of the global semis market from $600bn to $1 trillion by 2030E, we characterise it as a leading European Digital Enabler in our framework. While our view is not predicated on the transition to 3D DRAM, which we see as a longer-term dynamic, we note that the company's primary focus is on leading-edge applications (alongside a bias towards Logic/Foundry over Memory), which we see as positive exposures in the current environment relative to other companies in our Europe Semis/Hardware coverage.

- While we acknowledge that the **stock** is **up around 91% in the last two years**, we note that **our EBIT estimates are 5%-7% ahead of consensus on 2024/25**. **Moreover, we highlight, as summarised in the exhibit below, that our view differs from consensus based on our more bullish view on growth drivers such as the transition to Gate-All-Around** transistor structures **and the scope to benefit from leading-edge node shrinkage.** While the **largest portion of orders today relate to FinFET transistor architectures**, the company has started to receive Gate-All-Around orders and has already **announced a key customer win** (undisclosed name) for **advanced CMOS Epitaxy tools for Gate-All-Around applications, supporting our longer-term above-consensus 2024/25 estimates.**
- Moreover, while we believe it is reasonable to ask as to what degree the stock can perform until the SOXX (semis index) rebounds, we note that the company has one of the better end market/technology transition exposures in our Digital Enablers coverage, on a relative basis, in the current fluid macro environment, as highlighted graphically below. In particular, we note that ASMI has a **superior position in a number of positive megatrends** (e.g. transistor transitions in leading-edge Logic and semicap re-shoring benefits) with **limited risk/exposures in more challenging trends/areas** (e.g. cost/wage inflation, consumer/gaming weakness, trailing-edge semis cyclicality and memory exposure).
- Furthermore, we believe that after a **57% de-rating of the valuation multiple since its peak in November 2021**, the stock currently offers an **attractive entry point** on a relative basis. In particular, the stock now offers a **4x higher 2-year forward growth delta** (compared to semicap peers) vs over the last 8 years, **but trades on only a c.1.3x higher premium** (vs semicap peers) than historical average delta to peers.

Exhibit 29: Our above-consensus numbers are driven by a more positive view on Gate-All-Around and favourable end-market exposure (especially leading-edge logic)



Source: Goldman Sachs Global Investment Research

Exhibit 30: ASMI has one of the more favourable relative near-term end-market exposures within our European Tech Hardware coverage, with a positive risk/reward skew

	RATING	Leading-edge vs Trailing-edge	Outsized Logic Exposure	Geo political/ Re-shoring benefits	Outsized consumer exposure	Outsized Memory exposure	Outsized wireless comms/ Data centre exposure	FX risk	China domestic risk	Energy cost risk	Outsized auto exposure	Current Trading Premium/ Discount vs EU Tech	10Y Median Premium/ Discount vs EU Tech	12M PT upside vs downside scenario	Delta between current growth premium/ discount vs 10Y hist. avg.
ASM	BUY	▲	▲	▲	△	△	△	△	△	▲	△	31%	17%	3x	1.5x
ASML	BUY (ON CL)	▲	▲	▲	△	△	△	▲	△	△	△	48%	32%	3x	1.1x
Infineon	BUY	△	△	△	▲	▲	△	△	△	△	▲	-32%	-29%	3x	0.7x
STM	NEUTRAL	△	△	△	△	▲	△	△	△	△	△	-52%	-40%	1x	0.5x
ERICSSON	BUY (ON CL)	NA	NA	▲	△	NA	▲	▲	▲	▲	NA	-61%	-37%	2x	1.1x
NOKIA	BUY	NA	NA	▲	△	NA	▲	△	▲	▲	NA	-51%	-41%	1x	1.0x
logitech	BUY	NA	NA	NA	△	NA	NA	△	△	▲	NA	102%	-22%	2x	0.9x
STILLFRONT	BUY	NA	NA	NA	△	NA	NA	△	▲	▲	NA	-44%	-32%	4x	0.3x
EMBRACER GROUP	NEUTRAL	NA	NA	NA	△	NA	NA	△	▲	▲	NA	-34%	-28%	NM	0.4x
CD PROJEKT	SELL	NA	NA	NA	△	NA	NA	△	▲	▲	NA	94%	7%	NM	0.0x

NM: Not meaningful ▲ Best-Positioned △ Average Positioned △ Worse Positioned

Source: Goldman Sachs Global Investment Research, Eikon Datastream

ASMI is well positioned in both ALD and Epitaxy, two of the highest value-add technologies within the semicap equipment market, in our view

ASMI holds a **market-leading 55% share in single-wafer Atomic Layer Deposition (ALD) tools**, **the most advanced deposition method available today,** which are used to deposit **critical layers at leading-edge technology nodes, one atomic layer at a time**, forming extremely thin films of uniform thickness. While peer AMAT has the largest share in Epitaxy, which is used for depositing crystalline films onto wafers, we note that ASMI is the second-largest player with a 15% share and has articulated a target to double this figure.

- While **single-wafer ALD is the company's largest product line**, comprising over half of 2021 equipment revenue, ASMI also has **exposure to the fast-growing Epitaxy market** (Epitaxy is a process for depositing highly controlled silicon-based crystalline films), which we see as a **strong auxiliary growth driver** for the company.
- We expect **ASMI to benefit from increased adoption of single-wafer ALD and Epitaxy tools, as leading-edge Logic/Foundry players continue to transition to smaller and more powerful nodes, i.e. shrink** (driving the need for more complex deposition techniques), as well as **strong uptake related to the upcoming transistor architecture shift to Gate-All-Around structures.**
- We forecast a **2021-25 organic revenue CAGR of 19% at a group level**, primarily driven by our view of continued growth momentum in single-wafer ALD and Epitaxy markets. We are **3%/5%/7% above Visible Alpha Consensus Data on FY23/24/25 EBIT**, which we believe reflects a more **bullish view on growth drivers such as the transition to Gate-All-Around** transistor structures, **continued node shrink at leading Logic/Foundry** players, and **favourable end-market exposure** relative to other semicap players.

Exhibit 31: ASMI focuses on front-end semis production equipment, with a minority stake in back-end assembly/packaging (ASM PT)

Source: Company data, data compiled by Goldman Sachs Global Investment Research

Exhibit 32: ASMI supplies deposition machines, with a leading position in single-wafer atomic layer deposition (ALD) and an expanding presence in Epitaxy (Epi)

ASM International: Overview	
What is it?	• **Wafer deposition machines, services and parts** for semis makers, in $94bn Wafer Fab Equipment (WFE) market (GSe, 2022) • **Leading position in single-wafer Atomic Layer Deposition** (ALD), latest technology to **deposit ultra-thin and uniform films, atom-by-atom** • **Expanding presence in Epitaxy** (Epi); fast growing market for **depositing silicon crystalline films**
Competition	• **~55% market share in single-wafer ALD** and **~15% share in Epi;** competitors **Applied Materials, Lam Research and Tokyo Electron** • ASMI aims to further expand **ALD single-wafer market share to >55% by 2025**, with **>30% share in the Epi** market.
Growth Drivers	• **Node shrinkage for advanced Logic/Foundry** requires **thinner films**; **deposition at atomic level** is best • **Architectural transitions** (e.g. FinFET to **Gate-All-Around**) and planar to **3D DRAM** will require **more precise** deposition • **Semis market to grow to $1tn by 2030** (from c$600bn today) and catalyse higher **WFE spending** (mature and leading-edge)
Market Growth	• ASMI expects **ALD market to grow to $3.1-3.7bn** by 2025 (vs $1.5bn in 2020) i.e. **20% CAGR** • ASMI expects **Epi market to grow to $1.5-1.8bn** by 2025 (vs $0.8bn in 2020) i.e. **18% CAGR**
Valuation	• **CY23 Trading multiples:** €11bn Market Cap; 4x EV/Sales; 12x EV/EBITDA; 17x forward PE • **12m PT of €365** (57% upside); based on 19x CY23 EV/EBITDA
Catalysts	• **Positive earnings revisions** (GSe above cons on 2024/25 ests.) • Faster shift to **Gate-All-Around** architecture

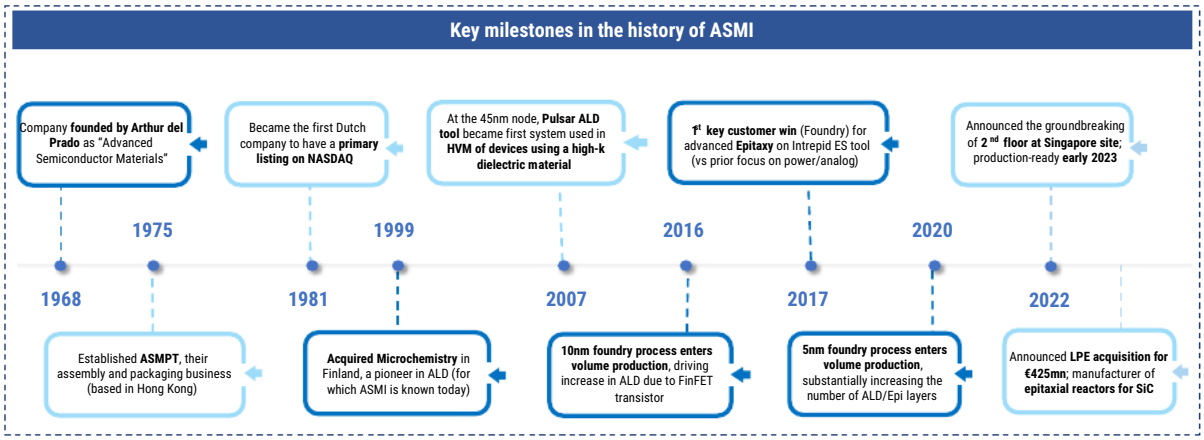
Market share data per ASMI

Source: Company data, Goldman Sachs Global Investment Research

ASMI has steadily built scale through its multi-decade history in the semicap deposition market, with key customer wins in ALD and Epitaxy validating its strong competitive position.

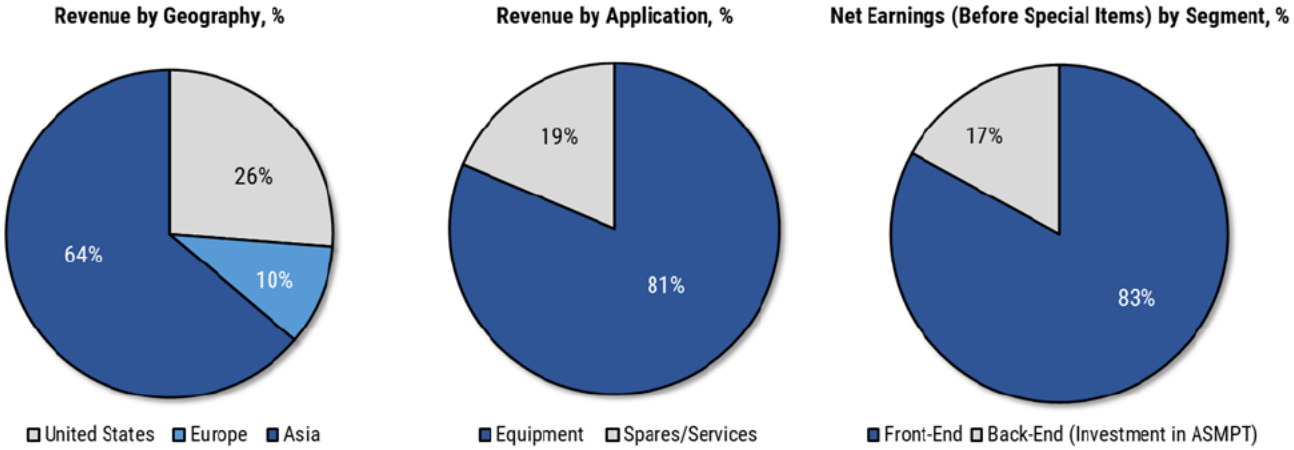
- We see the **acquisition of Microchemistry, which first pioneered ALD, as a key inflection point for ASMI**. Post the acquisition, the company further developed the ALD technology for a number of years before securing the **first key ALD customer win at a key IDM player in 2007 for the Pulsar ALD tool in high volume manufacturing of devices using a high-k dielectric material. As per the company's press release, in 2007, ASMI had already installed more than 30 Pulsar process modules for pilot and volume production with multiple leading IDM and foundry customers.**
- Key additional milestones, in our view, include the company's **first key customer win for advanced Epitaxy applications with a leading Foundry player in 2017**, enabling it to **expand market share in Epi** (given ASMI lacked leading-edge Epi exposure prior to this, having concentrated on power/analog), which we see as a strong auxiliary growth driver.
- More recently, **ASMI has indicated its intention to further diversify its portfolio through its proposed (July 2022) acquisition of LPE**, a manufacturer of **epitaxial reactors for *Silicon Carbide,*** which should position the company well, in our view, to **benefit from the accelerated uptake of SiC-based power devices for EVs/solar** (see more in our report: *More bullish view on Silicon Carbide for European Digital Enablers*).

Exhibit 33: ASMI has decades of experience in semis equipment and deposition, with key wins underlining its strong market position
Key milestones in the history of ASMI



Source: ASM International, data compiled by Goldman Sachs Global Investment Research

Exhibit 34: Equipment sales comprise majority of revenues, with Asia representing the largest geo market
LHS: Revenue by geography | Centre: Revenue by application | RHS: Net earnings by segment



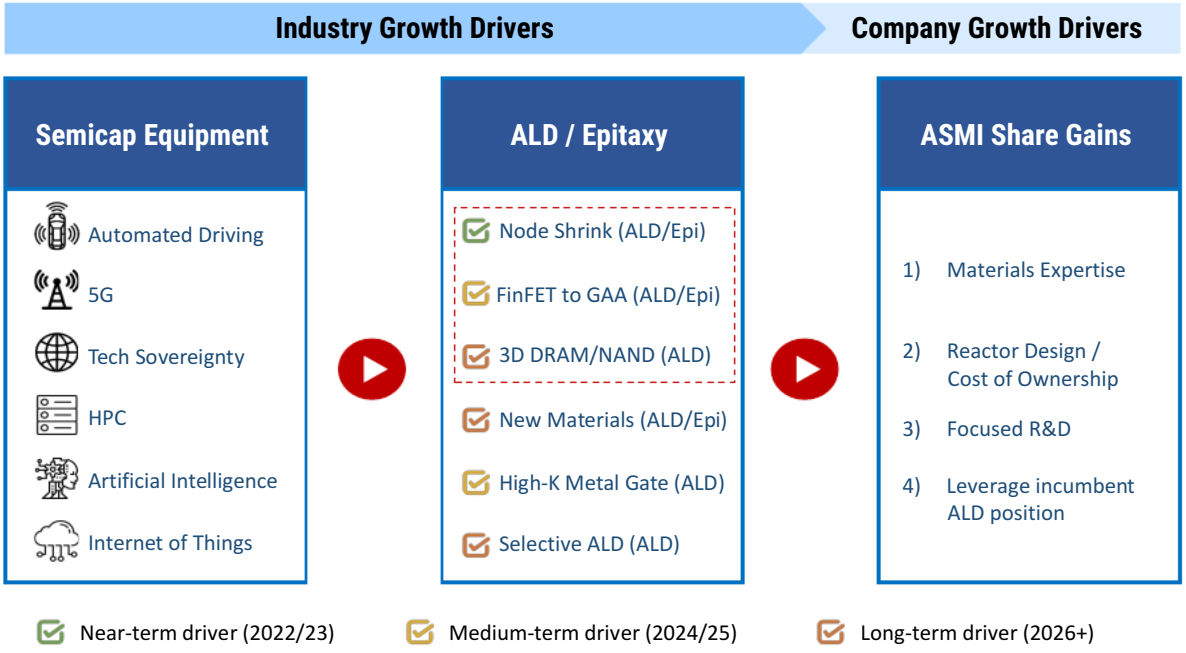
NB: 2021 figures

Source: Company data, Goldman Sachs Global Investment Research

Multiple compelling drivers underpin the growth story including Gate-All-Around transition and Logic leading-edge node shrinkage

We see multiple compelling growth drivers for ASMI, with our more bullish view relative to consensus driven by 1) the transition to Gate-All-Around transistor structures in Logic, 2) continued node shrinkage at leading-edge Logic/Foundry players, and 3) favourable end-market exposure relative to other semicap players. While we are more cautious on 4) benefits related to the transition to 3D DRAM near term, we see scope for this to be a longer-term driver.

Exhibit 35: ASMI is benefitting from a broad set of near-term and long-term drivers, in our view



Source: Goldman Sachs Global Investment Research

- **We expect ASMI to experience a net strong benefit from continued node shrinkage** and see supporting evidence in the fact that the **Foundry transition to N5 (industry 7nm), which was the first major insertion of EUV, led to a strong inflection for ALD applications**. Overall, we expect EUV-enabled node shrink to be a strong driver in the medium term and note that **ASMI has secured multiple new (double-digit % increase) ALD layers and applications for the next node transition** (which is expected to ramp up into **high volume manufacturing in 2H22/2023).** ASMI has also had success in penetrating non-patterning applications such as in DRAM (memory), where **ALD/Epitaxy is used during the development of peripheral transistors**, which are essentially **logic-like layers within memory cells.** Overall, we expect **continued node shrink to be a near-term driver, catalysing growth in a number of ASMI's ALD applications in 2023/24.**
- We believe that the **transition to Gate-All-Around transistor architectures in the logic space will be a significant inflection point for ASMI**, given our view that increasingly **more emphasis will be placed on Epi to build up the transistor channel,** along with incremental **ALD applications to construct the transistor gate**. As such, we expect the Gate-All-Around transition to be a meaningful revenue driver in the medium term (e.g. 2024 onwards) and note that the company expects the **new Gate-All-Around structure to drive incremental TAM growth of $1.2bn by 2025. This compares to the overall market size of ALD and Epitaxy of $2.5bn in 2020, and, in our view, highlights significant growth opportunities.**

Exhibit 36: Logic/Foundry spending growth driven by the transition to Gate-All-Around; 3D DRAM potentially more longer term
Technological trends by end market

Process Node	N		N+1		N+2		N+3		>N+4	
HVM Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
DRAM	Planar DRAM						3D DRAM			
3D NAND	Single to Multi-Tier 3D NAND								Novel Concepts	
Logic/Foundry	FinFET 5nm → 3nm				Gate-All-Around 2nm				FS-GAA 1.5nm → 1nm	
Customer Activity	HVM		Pilot Production		Development		Pathfinding		Exploration	
ASMI Activity	Support HVM		PTOR Selection		DTOR Selection		First demos, Pathfinding JDP		External R&D, Scouting	

FS: Fork Sheet | HVM: High Volume Manufacturing | PTOR: Production Tool-of-Record | DTOR: Development Tool-of-Record | JDP: Joint Development Program

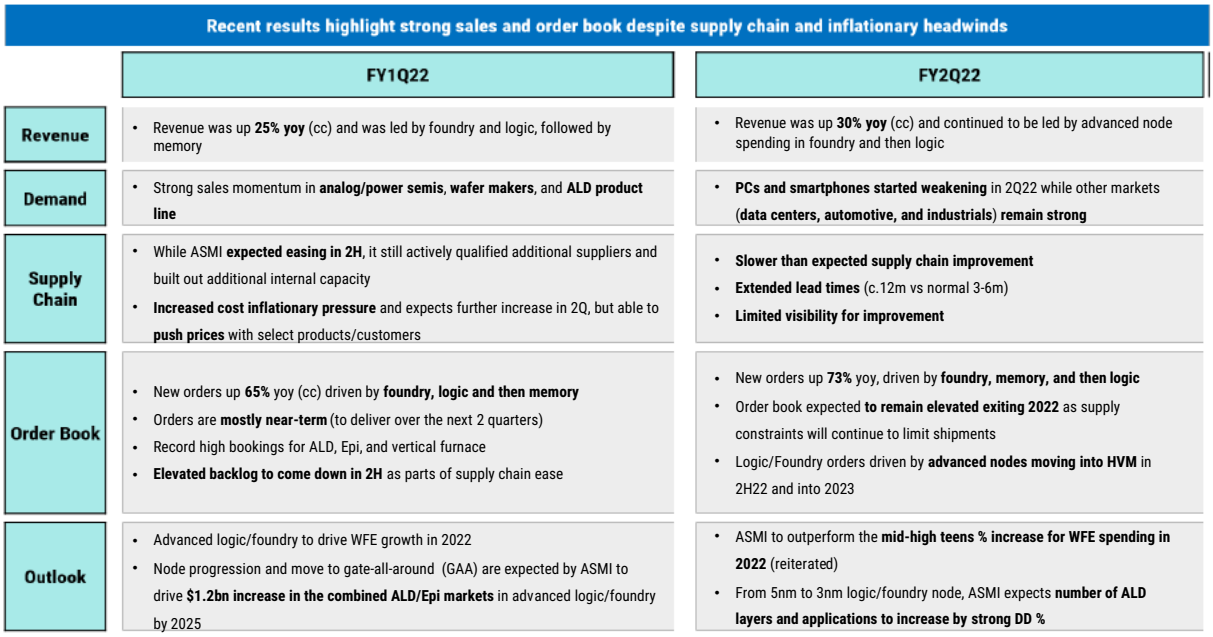
Source: Company data, Goldman Sachs Global Investment Research

- In our view, **vertical scaling of 3D structures in DRAM and NAND Memory is likely to drive an increased market opportunity for ASMI's single-wafer ALD** business. ASMI has been gradually expanding its presence in 3D NAND, and benefited from strong spending in 1H22, e.g. gap-fill wins. That said, while **ASMI is already in early engagement with leading customers on 3D DRAM**, we are **cautious on the likelihood of a near/mid-term transition to 3D DRAM structures**, noting mixed commentary from key Memory players. We still see more room for **node migration within the current 2D DRAM structure using EUV** and believe it could take **5-10 years for mass production of 3D DRAM**, suggesting that incremental growth from 3D stacking could be a **longer-term dynamic. As such, we see the 3D DRAM transition as a longer-term benefit for ASMI.**
- Separately, we see **ASMI as well-positioned with all the leading logic manufacturers to benefit from more intensive use of high-k gates** as the market continues to develop, such as during the transition to Gate-All-Around. Further, we believe **ASMI has sold high-k metal gate ALD tools to all major DRAM customers and is engaged with customers for ALD applications at future DRAM nodes.** For example, the company has benefited in recent quarters from **strong adoption of high-k metal gates in DRAM peripheral transistors (which are deposited using ALD)**. As such, we expect this **mature growth driver to drive new single-wafer ALD applications for ASMI in both near and longer term.**
- Lastly, longer term, **ASMI sees scope for several incremental applications of selective ALD** (i.e. depositing materials in specific locations on the chip), but they still need to be qualified and developed and therefore will **not likely generate revenue before 2024/25.** As such, we see this growth driver as a **long-term blue-sky scenario** and believe that any potential impact is likely to become **more meaningful only beyond 2025+.**

Exhibit 37: Near-term growth drivers to support strong 2022/23, in our view

Source: Company data, Goldman Sachs Global Investment Research

Exhibit 38: Recent company results highlight strong sales and order book despite supply chain and inflationary headwinds



	FY1Q22	FY2Q22
Revenue	• Revenue was up **25% yoy** (cc) and was led by foundry and logic, followed by memory	• Revenue was up **30% yoy** (cc) and continued to be led by advanced node spending in foundry and then logic
Demand	• Strong sales momentum in **analog/power semis**, **wafer makers**, and **ALD product line**	• **PCs and smartphones started weakening** in 2Q22 while other markets (**data centers, automotive, and industrials**) **remain strong**
Supply Chain	• While ASMI **expected easing in 2H**, it still actively qualified additional suppliers and built out additional internal capacity • **Increased cost inflationary pressure** and expects further increase in 2Q, but able to **push prices** with select products/customers	• **Slower than expected supply chain improvement** • **Extended lead times** (c.12m vs normal 3-6m) • **Limited visibility for improvement**
Order Book	• New orders up **65%** yoy (cc) driven by **foundry, logic and then memory** • Orders are **mostly near-term** (to deliver over the next 2 quarters) • Record high bookings for ALD, Epi, and vertical furnace • **Elevated backlog to come down in 2H** as parts of supply chain ease	• New orders up **73%** yoy, driven by **foundry, memory, and then logic** • Order book expected **to remain elevated exiting 2022** as supply constraints will continue to limit shipments • Logic/Foundry orders driven by **advanced nodes moving into HVM** in 2H22 and into 2023
Outlook	• Advanced logic/foundry to drive WFE growth in 2022 • Node progression and move to gate-all-around (GAA) are expected by ASMI to drive **$1.2bn increase in the combined ALD/Epi markets** in advanced logic/foundry by 2025	• ASMI to outperform the **mid-high teens % increase for WFE spending in 2022** (reiterated) • From 5nm to 3nm logic/foundry node, ASMI expects **number of ALD layers and applications to increase by strong DD %**

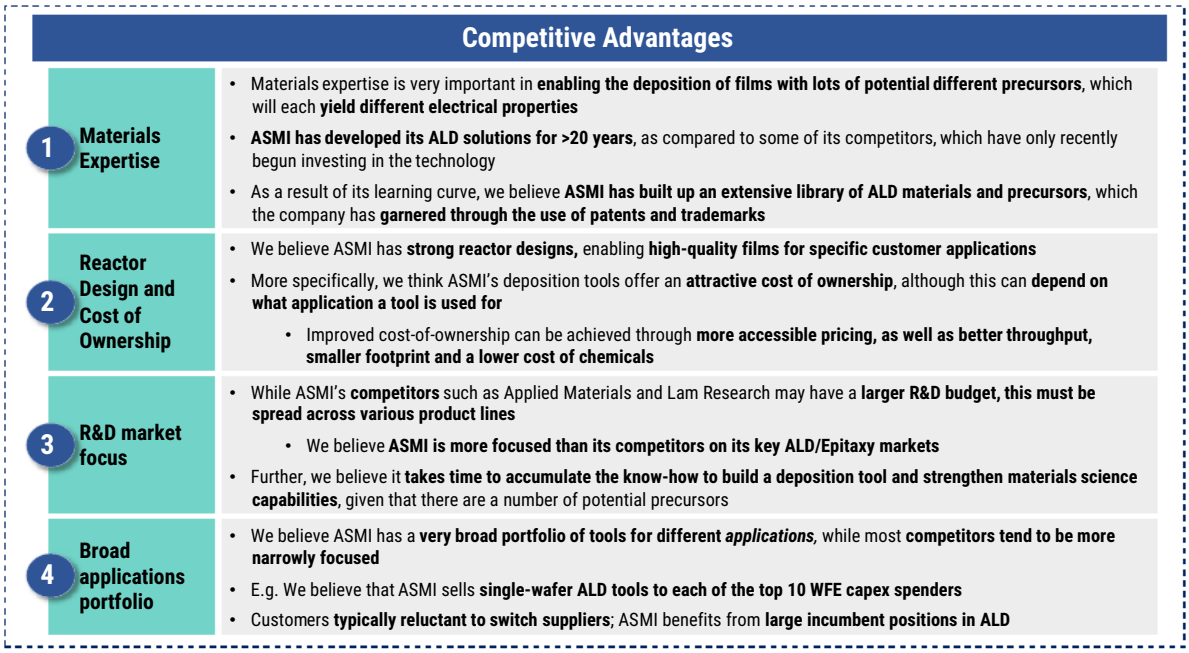
Source: Company data, data compiled by Goldman Sachs Global Investment Research

We see scope for ASMI to maintain its strong positioning in ALD due to its materials expertise, robust reactor design and attractive cost of ownership

As illustrated below, we believe ASMI can maintain its strong positioning in single-wafer ALD due to factors including its materials expertise, robust reactor design, focused R&D

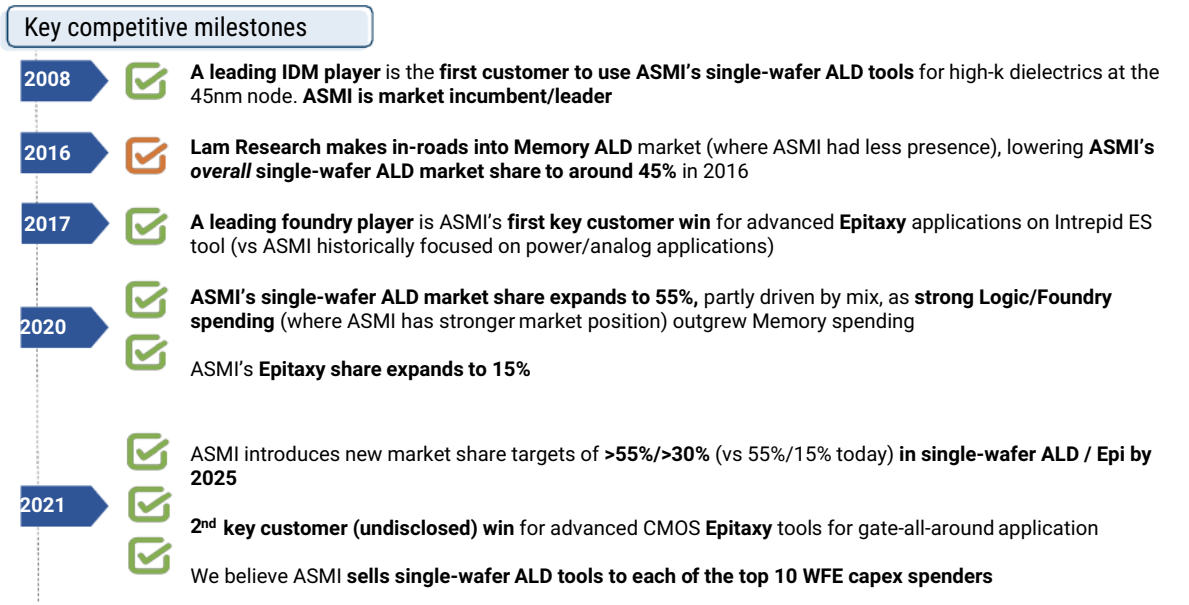
approach and attractive cost of ownership.

Exhibit 39: We see scope for ASMI to maintain its strong positioning in ALD due to its materials expertise, robust reactor design and attractive cost of ownership...
Overview of ASMI's competitive advantages



Source: Company data, Goldman Sachs Global Investment Research

Exhibit 40: ...with key customer wins already and room for further customer traction that will support ASMI's ongoing share gain trajectory in both ALD and Epi, in our view



Source: Company data, Goldman Sachs Global Investment Research

New materials are increasingly utilised in the production of next-generation chips to improve factors such as electrical properties, in particular as films become

thinner and stacks become more complex. We see ASMI's 20+ years of ALD materials expertise and know-how as a key source of competitive differentiation that can underpin its strong share in this market.

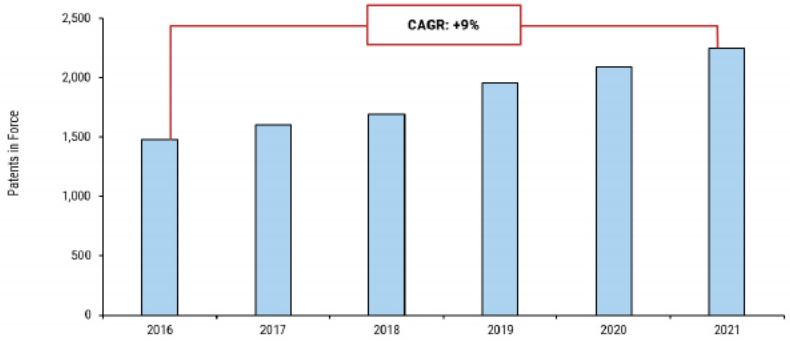
- **ASMI expects that around 50% of the known elements will be used in the semis industry in the next decade**, with **ALD being the best-suited technology that has the flexibility to deposit a wide range of materials**.
- We note that the transition to Gate-all-Around will require new materials to be deposited to maintain electrical performance, and we see ALD helping deliver precise deposition solutions.
- We see **ASMI's 20+ years of ALD materials expertise and know-how as a key source of competitive differentiation**, as compared to some competitors which only recently began investing in ALD technology. We believe that **ASMI has likely garnered an extensive library of ALD material and precursors**, which the company **protects through the use of patents** and trademarks.

Exhibit 41: ASMI's ALD reactors have the flexibility to deposit new, more complex materials, positioning it well for future semis processing innovations

ASMI's ALD reactors have the flexibility to deposit new, more complex materials	
What is happening?	• **New materials are increasingly required** for next-generation chips in order **to improve factors such as electrical properties**, in particular **as films become thinner and stacks become more complex** • Around **50% of the known elements will be used** in the semis industry **in the next decade**, per ASMI (2021 CMD)
What is the market opportunity?	• **ALD is the optimal technology to deposit new materials**, as it offers the highest level of precision • In the transition to **gate-all-around**, **new materials** (such as better conductors) are **needed to maintain electrical performance** • In **DRAM**, continued **scaling is partly driven by the use of better conductors and insulators** • In **3D NAND**, **new material for the vertical channel**, as well as conductors and gap-fills, **are needed for further stacking**
How does this benefit ASMI?	• ASMI possesses **20+ years of accumulated know-how in ALD materials and chemistries** (2021 CMD) • For example, ASMI's **Pulsar tool is the industry workhorse** for depositing hafnium-oxide-based high-k gates (2021 CMD) • ASMI also leverages its **EmerALD and Synergis tools** to deposit carbides/nitrides and metal oxides, respectively (2021 CMD)
Short-term vs. long-term?	• We see the flexibility of ASMI's tool portfolio as a **long-term competitive advantage and growth driver**

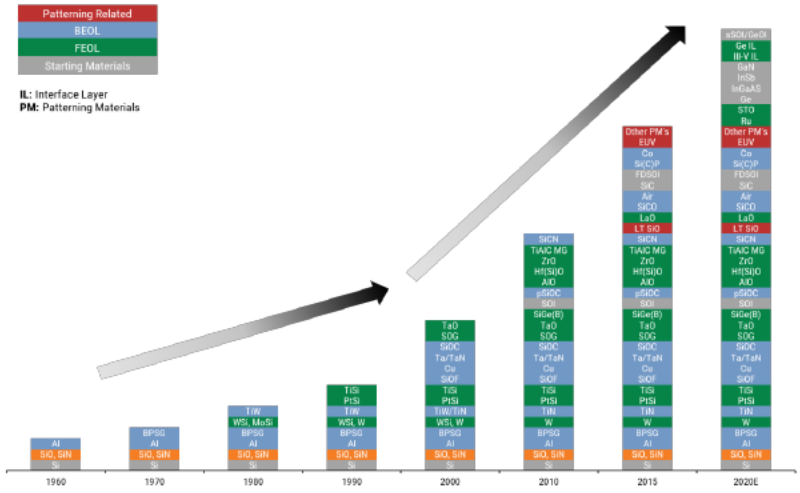
Source: Company data, Goldman Sachs Global Investment Research

Exhibit 42: ASMI captures the value added by its materials science expertise through its extensive patent portfolio
ASMI patent portfolio



Source: Company data

Exhibit 43: ASMI has built up 20+ years of expertise in materials science, which we believe has contributed to the development of novel deposition materials
Materials used in chip making, 1960-present



Source: Company data

We believe ASMI has a very broad portfolio of single-wafer ALD and Epitaxy tools for different *applications*, while most competitors tend to be more narrowly focused in terms of tools/application types.

- We note that **chip makers are typically reluctant to switch suppliers in successful partnerships**, which we see as supporting **ASMI's large incumbent position (c.55% share) in single-wafer ALD.**
- While this dynamic **may make it more challenging for ASMI to gain share in the Epitaxy** market, we note that the company has already **successfully expanded into the advanced CMOS Epitaxy market** (with a first key Foundry customer win in 2017, having only been exposed to the much smaller power/analog Epi market

prior to 2017) and has **recently announced a second key win for advanced Epitaxy with Gate-All-Around (logic) applications**, which we believe demonstrates the **suitability of ASMI's technology for the upcoming transistor architecture transition.**

- As such, we expect **further customers wins for advanced Epitaxy tools to support ASMI's target to increase its market share by 2025 (GSe 20% in 2025). Note that we estimate a 63% share in ALD by 2025 vs the company's target of >55% and a share of 55% today.**

Exhibit 44: ASMI's broad product portfolio covers ALD, Epitaxy, CVD, and Batch ALD applications
ASMI product applications and descriptions

ASMI Product Applications and Descriptions

Deposition Application	ASMI Product Platform	ASMI Products	Process Application	Comments
ALD	XP	• **Pulsar XP ALD System** • **EmerALD XP ALD System**	• High-k gate dielectric • Metal gate layers	• **Pulsar/EmerALD focused on advanced applications**
	XP8	• Synergis ALD System	• Metal oxides, metal nitrides, metals	• Synergis focused on high-productivity
Plasma-enhanced ALD	XP8	• Eagle XP8 PEALD System • XP8 QCM PEALD System	• Patterning layers • Gate spacers and liners • Gapfill	• Used for applications with low thermal budgets • High productivity tools
Vertical Furnaces / Batch ALD	Vertical Furnace (Batch Tools)	• A412 Batch Vertical Furnace System • A400 DUO Batch Vertical Furnace System	• Diffusion, oxidation • Polysilicon • Silicon oxide/nitride • Aluminum oxide	• High productivity tools processing large numbers of wafers at same time, but lower precision
Epitaxy	XP	• **Intrepid ES Epitaxy** • **Intrepid ESA Epitaxy**	• Silicon channel • Source/drain layers • CMOS wafers • Analog/power	• **Intrepid ES** focuses on **advanced node applications** • Intrepid ESA (launched 2021) focuses on **analog/power** etc • **Epsilon** focuses on **200mm power/analog**
	Epsilon	• Epsilon 2000 Single-Wafer Epitaxy System		
PECVD	XP8	• Dragon XP8 PECVD System	• Low-k and TEOS oxide • Silicon nitride	• High productivity deposition

Source: Company data, Goldman Sachs Global Investment Research

Exhibit 45: ASMI has a broad portfolio of deposition equipment for both leading-edge and legacy processes
ASMI technology product matrix

			Process Technology Platform				
			ALD	LPCVD & Diffusion	Epitaxy	PECVD	PEALD
Product Platform	XP	Intrepid ES			✓		
		Pulsar XP	✓				
		Emerald XP	✓				
	XP8	Dragon XP8				✓	
		Eagle XP8					✓
		Synergis	✓				
		XP8 QCM					✓
	Epsilon	Epsilon			✓		
	Vertical Furnace	A412		✓			
		A400 DUO		✓			

LPCVD is Low Pressure Chemical Vapor Deposition

Source: Company data

Our above-consensus estimates are driven by our constructive views on Logic node shrinkage and the transition to Gate-All-Around, with ASMI having sales concentrated in relatively favourable areas, i.e. leading edge Foundry/Logic

While we see multiple compelling growth drivers for ASMI, we are more positive on 1) ASMI's exposure to continued node shrinkage at leading-edge Logic/Foundry players, 2) structurally higher demand for advanced deposition techniques catalysed by the upcoming Gate-All-Around transistor shift, and 3) ASMI's favourable near-term production positioning, with sales concentrated at leading-edge Logic/Foundry customers. While we conceptualise 3D DRAM as a longer-term driver, rather than a near-term benefit to earnings, we see a positive risk-reward skew overall for ASMI on a 12-month basis.

- We note that the transition to Gate-All-Around is already underway within the Foundry/logic space and are constructive on ASMI's scope to benefit. We highlight that **Samsung is the first major player to have already started (June 2022) mass production of 3nm Gate-All-Around chips**, with the company also on track to introduce a **2nd generation Gate-All-Around process into mass production in 2024**, as detailed in the exhibit below. While **Intel and TSMC** plan to use FinFET transistors at the upcoming node transition (vs Samsung using Gate-All-Around), we note that both companies **target mass production of Gate-All-Around products on their technology roadmaps in 2024/25.**
- Moreover, we highlight that **ASMI has already announced a key customer win (undisclosed name) for advanced CMOS Epitaxy tools for Gate-All-Around applications**. While the largest portion of orders today relate to FinFET transistor

architectures, the company **has started to receive Gate-All-Around orders in small volumes**. Moreover, we note that **ASMI is currently engaged in development work with all three key Logic/Foundry customers on Gate-All-Around**. As such, given that ASMI expects **Gate-All-Around** to **generate a double-digit percentage increase in ALD applications**, and the early **tangible evidence of customer wins**, we see a significant TAM expansion opportunity in the medium term.

Exhibit 46: Samsung introduced Gate-All-Around in 1H22, with TSMC/Intel also working on Gate-All-Around products
Key customer technology roadmaps for Gate-All-Around

Gate-All-Around (GAA) Technology Roadmap

Company	Name of GAA technology	First GAA Process Node	Volume Production Timeline	Comments
Samsung	Multi-Bridge-Channel FET (MBCFET)	3GAE (3nm)	June 2022	• **Reduced power consumption** up to 45%, **improved performance** by 23%, and **reduced area** by 16% compared to its 5nm node
Intel	RibbonFET	20A (2nm)	1H2024[1]	• To introduce new transistor **RibbonFET** (GAA) and power delivery innovation **PowerVia…** • **…delivering up to a 15% performance per watt improvement.**
TSMC	GAAFET	N2 (2nm)	2025	• **10-15% performance improvement** with offered support for **backside power distribution network** • **Risk production to begin in EOY 2024**

1. Manufacturing-ready timeline

Source: Data compiled by Goldman Sachs Global Investment Research

- Furthermore, **commentary from key semicap peers (and chip makers) suggests meaningful impetus to adopt Gate-All-Around technology in the medium term**. While ASMI expects the new **Gate-All-Around structure to drive TAM growth of $1.2bn by 2025**, we note that AMAT also sees significant opportunities and expects **Gate-All-Around to grow the transistor TAM by more than $1bn per 100kwspm**. From a chip-maker perspective, we highlight that **Samsung expects its first-generation 3nm Gate-All-Around process to reduce power consumption by up to 45%** vs the 5nm process, which is encouraging for more broad-based Gate-All-Around adoption, in our view.
- That said, we believe **commentary on the potential timelines of mass adoption of 3D DRAM remains more mixed.** In particular, we note that **Samsung stated at its 2021 Investor Forum that it believes using EUV technology will enable the company to introduce sub-5nm DRAM within the next 10 years,** suggesting that 3D DRAM could potentially be a longer-term dynamic, in our view. Supporting this, ASML recently (June 2022) stated that **2D scaling will be on customer roadmaps for at least another 5-10 years**. Moreover, **Lam Research has stated that the transition to 3D DRAM may not be as strong as the transition from planar to 3D NAND**. As such, GS believes that there is still **more room for process migration using EUV,** and while 3D DRAM is not being actively discussed among

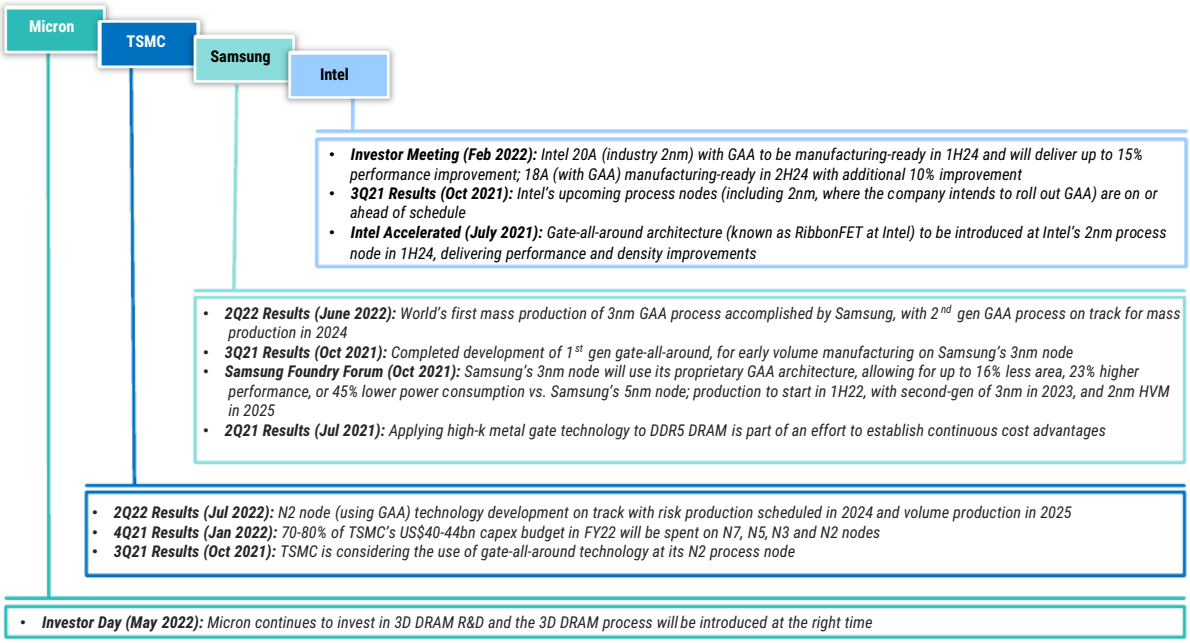
the DRAM makers, it is something to be **monitored in the long term** (see more here: *DRAM deep-dive: Shorter cycles within the structural growth to a US$100bn+ industry; upgrade Hynix to Buy*).

Exhibit 47: Commentary suggests a meaningful market opportunity from Gate-All-Around (Logic) in coming years, while 3D DRAM (Memory) transition could be a longer-term dynamic
Semicap commentary on Gate-All-Around and 3D DRAM

Applied Materials	• ***FY2Q22 Results (May 2022):*** *With GAA inflection, TAM for AMAT's transistor portfolio to grow by more than 15%* • ***FY1Q22 Results (Feb 2022):*** *Transition from FinFET to first-generation GAA to grow transistor TAM by more than $1bn per 100,000 wafer starts per month* • ***Technology Conference (Sep 2021):*** *GAA will begin to impact customer spending beyond 2024* • ***Conference (Sep 2021):*** *3D DRAM inflection to occur after transition to GAA* • ***Logic Master Class (Jun 2021):*** *GAA inflection should result in 25-30% lower power consumption and a 10-15% improvement in performance vs. FinFET* • ***TMT Conference (Jun 2021):*** *The market opportunity for 3D DRAM is around US$1bn*
Lam Research	• ***TMT Conference (Dec 2021):*** *The benefit of transitioning to 3D DRAM may not be as strong as the transition from planar to 3D NAND was, but it is going to be solid* • ***FY1Q22 Results (Oct 2021):*** *Device transitions from planar to 3D requires a lot of deposition equipment to build those complex structures* • ***TMT Conference (Jun 2021):*** *The transition to GAA is a positive in terms of SAM per wafer, in particular when it comes to deposition (and etch) intensity* • ***Conference (Jun 2021):*** *The acceleration to new layer counts in 3D NAND is very deposition and etch intensive*
ASML	• ***FY1Q22 Results (Apr 2022):*** *3D DRAM could be introduced sometime in 2025-2030* • ASML recently (June 2022) stated that **2D scaling will be on customer roadmaps for at least another 5-10 years**

Source: Data compiled by Goldman Sachs Global Investment Research

Exhibit 48: Samsung/Intel introduced/aim to introduce Gate-All-Around for Logic in 1H22/1H24, respectively, with TSMC considering the use of Gate-All-Around in its N2 process node
Semis producer commentary on Gate-All-Around and 3D DRAM



Source: Data compiled by Goldman Sachs Global Investment Research

We see a **strong roadmap for continued shrinkage at the leading-edge Logic nodes**

(partially enabled by complementary technologies such as Extreme Ultraviolet Lithography (EUV)), which increasingly require **greater uptake of more precise technologies such as single-wafer ALD and Epitaxy**, as more legacy deposition techniques such as physical/chemical vapor deposition gradually give sub-optimal results. We also believe that semicap spend related to leading-edge logic, an area where ASMI has significant exposure, may show a greater degree of resilience than other areas of the WFE market.

- We see scope for **leading-edge spending to show a greater degree of resilience** to potentially weaker macroeconomic conditions. We believe that if macroeconomic conditions were to significantly deteriorate, to the extent that this could be viewed as a short-term dynamic, **customers may not want to cancel tool orders as this could lead to the risk that they lack production capacity once a recovery happens** (and therefore lose business to other competitors).
- For example, we note that AMAT recently (August 2022) highlighted a **long-term race for leadership in leading-edge Logic as leading chip makers vie to be the first to implement major technology inflections** (e.g. Gate-All-Around, new materials etc), supporting continued growth in spending **despite the uncertain macro environment**, which we see as in line with our view of **robust ALD/Epi spending in 2023**.
- Furthermore, as a result of **ASMI's own idiosyncratic product ramps (e.g. ramping of single-wafer ALD for the upcoming node transition)**, we see **2023 growth as somewhat more decoupled from broader WFE dynamics than other more diversified semicap** equipment players, noting that **ASMI's addressable market only comprises around ~3% of the global WFE market.**

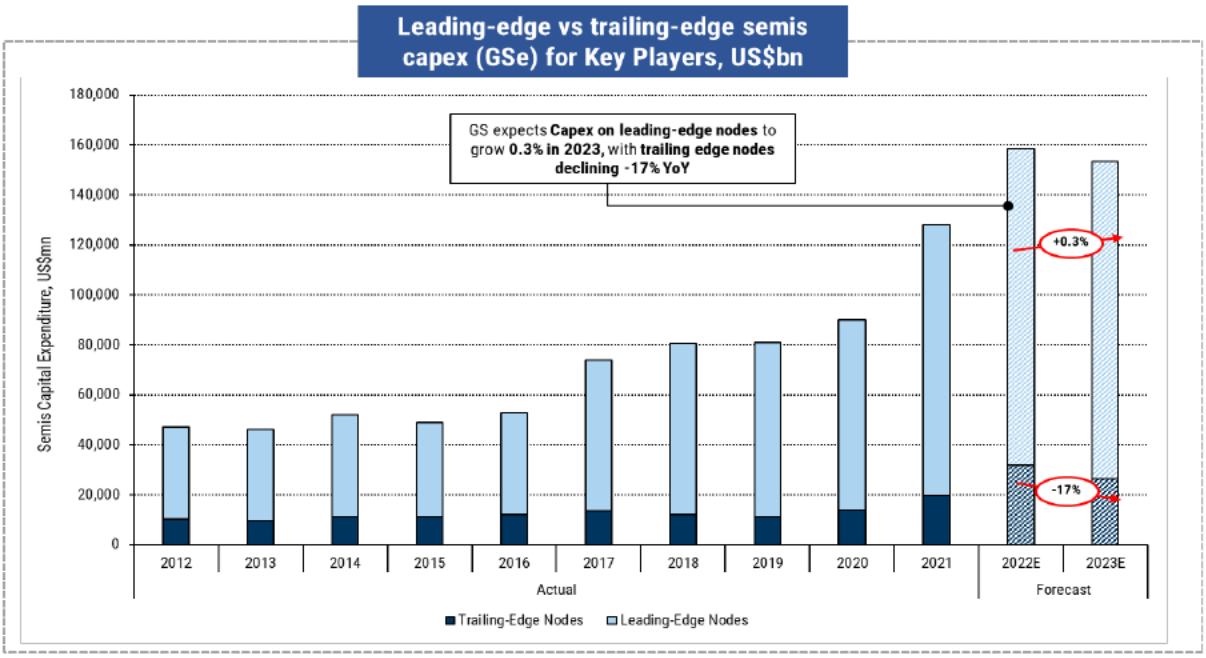
Exhibit 49: Latest datapoints from key Semicap equipment players suggest strength in leading-edge logic relative to other areas of WFE

Latest datapoints from key SemiCap equipment players			
Supply Chain Position	**Company**	**Commentary**	**Date**
SemiCap Equipment Manufacturers	Applied Materials	• AMAT noted **memory customers' desire to defer/cancel WFE** orders for **lagging edge nodes** • … **softness in consumer** but **strength in auto/industrial** and **leading-edge foundry/logic** demand • The company noted that the **importance of advancing transistor density and performance** is driving • … **leading-edge WFE** and is **supporting continued growth even against the uncertain backdrop**	18-Aug-22
	Lam Research	• LAM sees **strong foundry/logic spending** outgrowing **memory**, with no significant change in demand signals	28-Jul-22
	ASML	• ASML highlighted **strong lithography demand** for both advanced and mature nodes • … and a **Strong backlog**, of which **85% is for advanced semis** manufacturing	20-Jul-22
	Tokyo Electron	• TEL sees **no large-scale delays/cancellations or investment slowdowns** despite temporary softening in smartphones/PCs	08-Aug-22
	Lasertec	• Lasertec noted substantially **increased lead times**, with some orders to be shipped 2024 onwards • Orders driven by **new fabs in US and DRAM demand**	05-Aug-22
	Entegris	• Chip demand and capex activity to remain strong throughout 2022 • … as the **reduced capex plans** by **leading memory manufacturers** likely to be offset by the **accelerating node transitions**	03-Aug-22
Leading Semis Players	TSMC	• **TSMC lowered its 2022 capex guidance** with expectation of some being pushed out to 2023 • … but raised its 2022 revenue guidance, owing to **mid to HSD % silicon content growth and HPC demand**	14-Jul-22
	Intel	• **Intel** reduced **2022 gross capex budget following PC market weakness** and **consumer inventory cutbacks** in 2Q22 • Client and server CPU inventory dynamics was a headwind in 2Q22 and expected to continue in 3Q22	28-Jul-22
	Samsung	• Samsung **to adjust short-term investment and inventory** but reiterated its investment principle for mid-long term • **Server memory demand remains strong** while mobile demand weakened, impacted NAND more than DRAM.	28-Jul-22
	Micron	• Micron sees broader **weakening and inventory adjustment across most end markets** • including **automotive/industrials and cloud**, along with **more weakness in PC/smartphone/enterprise** • The **company is pushing out and cancelling WFE capex**, and expect FY23 capex down meaningfully vs FY22	09-Aug-22

Source: Data compiled by Goldman Sachs Global Investment Research

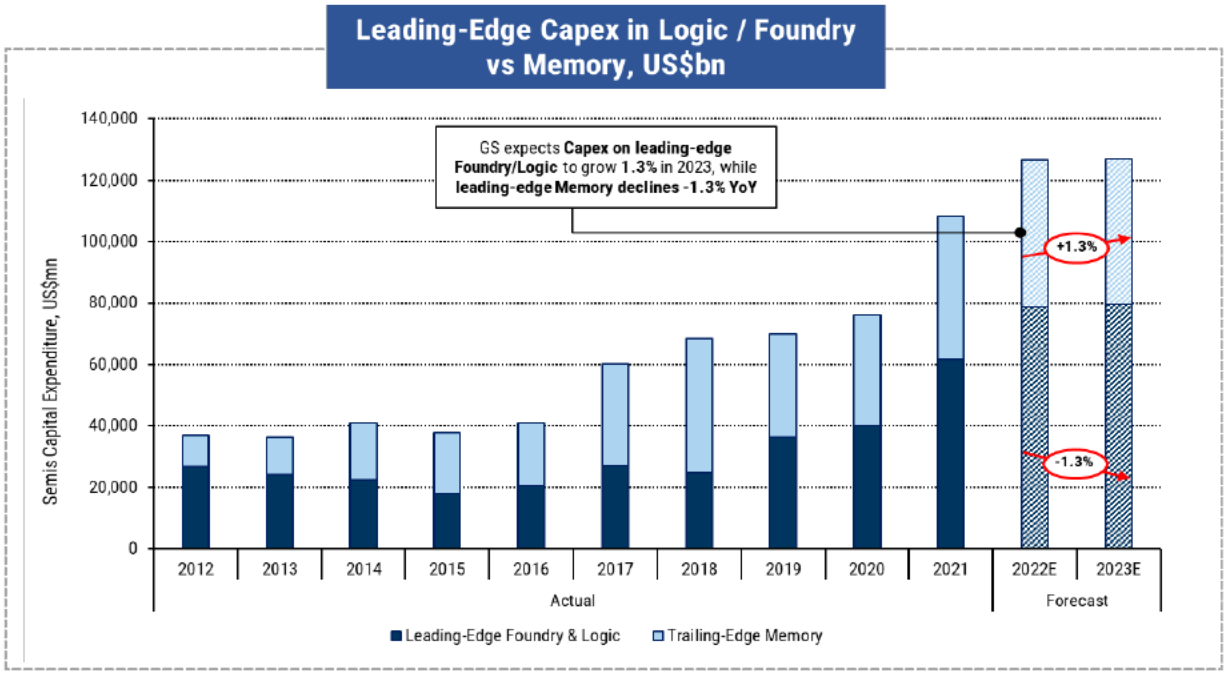
We also believe that **ASMI is relatively well-positioned to weather any near-term normalisation in semicap equipment spending**, given its favourable product positioning, i.e. a **bias towards leading-edge** (which we expect to outgrow lagging-edge spend in 2023) **Logic/Foundry** (which we expect to be more resilient than 2023 Memory spending).

Exhibit 50: ASMI to benefit from faster growth in leading-edge semis capex vs trailing-edge…
Capex by process node for key players, $bn (GSe)



Source: Company data, Goldman Sachs Global Investment Research

Exhibit 51: …with more exposure to faster-growing leading-edge Logic/Foundry than Memory
Logic/Foundry and Memory capex in leading-edge nodes for key players, $bn (GSe)



Source: Company data, Goldman Sachs Global Investment Research

- We note that our US Semis team expects **semiconductor capex on leading-edge**

nodes (where ASMI is most heavily exposed) **to grow 0.3% in 2023, compared to a -17.4% decline in lagging-edge capex spend,** as shown in the exhibit above. Moreover, within leading-edge spending, we note that **ASMI has significantly greater exposure to Logic/Foundry, which GS expects to outgrow lagging-edge Memory spending**. Indeed, we note that Micron (leading Memory player) has explicitly signalled a significantly more conservative capex outlook in light of weaker market conditions.

- Further, we also believe that **TSMC's recent (July 2022) upward revision of 2022 revenue guidance** (to mid-30%s yoy vs high 20%s prior), as well as expressed confidence in the 15%-20% long-term revenue CAGR target, supports our view that **advanced Logic/Foundry demand is *relatively* well positioned.** While TSMC did lower its 2022 capex guidance to the lower end of its prior $40-44bn range, we note that this was **primarily due to delayed delivery of some equipment for both advanced and mature node processes. Our Asia tech colleagues have lowered their estimates for TSMC 2023 capex** recently **to US$36bn from US$40bn**, partially based on 1) A certain level of **macro demand drawdown and** 2) **milder expansion in leading-edge processes (3/5/7nm)** due to weak android smartphone AP demand. That said, as a result of **ASMI's own idiosyncratic product ramps (e.g. ramping of single-wafer ALD for the upcoming node transition)**, we see its **2023 growth as somewhat more decoupled from broader WFE dynamics than other more diversified semicap** equipment players, noting that **ASMI's addressable market only comprises around ~3% of the global WFE market**.
- We also note **Samsung's** recently announced plan to **triple its advanced chip production capacity by 2027**, (with plans to start **mass production of 2nm/1.4nm chips by 2025/2027)** as evidence of solid long-term leading-edge Logic spending. The company highlighted that it sees the **demand for advanced nodes (<5nm)** increasing driven by **long-term expansion of HPC, AI, 5G/6G and automotive applications**. We note this **trend as a positive for ASMI**, given **its strong position in leading-edge applications** and the **significant role single-wafer ALD is expected to play in the future node transitions.**
- We also note that **Micron recently revised down its capex spending estimates** to reflect weakness in memory demand, albeit we expect **ASMI to see limited impact from this due to its lower exposure to memory and strong position in logic/foundry** (which we expect to be major drivers of growth going ahead), as well as a **strong order backlog.**
- We note that **AMAT sees a mixed demand outlook at the lagging-edge** (where ASMI is least exposed), while **leading-edge foundry and logic dynamics remain quite strong** (see more *here*). The company stated that some customers have deferred some capacity additions in Memory related to weakness in consumer/PC.

Bullish view on single-wafer ALD/Epitaxy market growth and market share assumptions at the top end of company targets drive above-consensus estimates

We are **bullish** on the **growth prospects of single-wafer ALD/Epitaxy** as we expect the **transition in logic/foundry to** Gate-All-Around and **leading-edge shrink to drive**

demand for ALD and Epitaxy equipment. As per ASMI, the single-wafer ALD/Epitaxy market is expected to grow to **$3.7bn/$1.8bn,** implying a **CAGR of 20%/18% over 2020-25E**. In the single-wafer ALD segment, we expect **ASMI** to have a **market share of around 63%** (vs ***company guidance of >55%***) in 2025 (vs 55% today), driven by **resilient spending in the logic segment benefiting the company** due to its **stronger market position here (vs memory), and the transition to Gate-All-Around architecture.**

For Epitaxy, we forecast that **ASMI will have a market share** of **around 20%** (***lower than company guidance of >30%***) in 2025 (vs 15% today). We assume that ASMI can **see a share gain of around 5pp based** on **1) ASMI's wins at a leading foundry player** for **advanced Epitaxy products in 2017 and a second key customer win for CMOS Epitaxy tool for Gate-All-Around (logic) applications**, **2) the launch of a new ES Intrepid tool in 2021 and several key customers wins,** which are expected to contribute to revenue in the near term, **3) strong technical capabilities of tools** providing **greater thermal control** and **efficiency** and an overall increase in throughput for customers, and **4) solid traction in the fast-growing epitaxy market for power/analog applications.** That said, we assume a **smaller share gain in Epitaxy than ASMI's targets for 2025** given its main competitor has a strong R&D position and robust technological track record.

Lastly, we forecast **total group revenues of €3.5bn** (higher than ***company guidance of €2.8bn-€3.4bn***) in 2025, driven by a **more positive view on ASMI's single-wafer ALD** vs. company guidance, and a slightly conservative but meaningful contribution from Epitaxy. Our **more positive view** is based on our expectation that **demand for ASMI's products in the logic/foundry segment will increase** due to a continuous need for **node shrinkage and improved efficiency,** and hence we forecast **single-wafer ALD/Epitaxy revenues** of **€2.3bn/€0.4bn in 2025,** implying a revenue CAGR of **23%/29% across 2021-25E.**

Exhibit 52: Our above-consensus estimates are driven by a bullish market outlook, with share gain assumptions broadly in line with company targets

Company	GS View	Comments / Key Datapoints
Market TAM	▪ **Single Wafer ALD/Epitaxy** industry to see **strong demand** ▪ **Bullish view** on FY25 TAM	▪ **Leading edge node shrinkages** and **architectural transitions** ▪ Assuming ALD/Epi market of **c$3.7bn/$1.8bn** (i.e. upper end of 2025 guidance) implying a **CAGR of 20%/18%** for 2020-25E
Market Share	▪ ***Maintain* single wafer ALD market share at c63% in 2025** (in-line with company guidance of >55%) ▪ ***Expand* market share in Epitaxy to c20% in 2025** (lower than company guidance of >30%)	▪ **ALD** share supported by **leading-edge node shrinkages** and **shift to GAA** in Logic/Foundry. ▪ **Epi** share supported by strong **customer traction for new advanced tools**.
Revenue CAGR	▪ **Bullish assumptions on market growth,** with more **moderate view on share gains** ▪ We forecast ALD/Epi revenue 2021-25 **CAGR of 23%/29%** ▪ GSe **2025 ahead of company guidance**	▪ We look for further **evidence of share gain in Memory** ▪ GSe **2025 single-wafer ALD/Epi revenues of €2.3bn/€0.4bn** ▪ GSe **2025 group sales of €3.5bn (vs guidance** range of €2.8bn-€3.4bn)

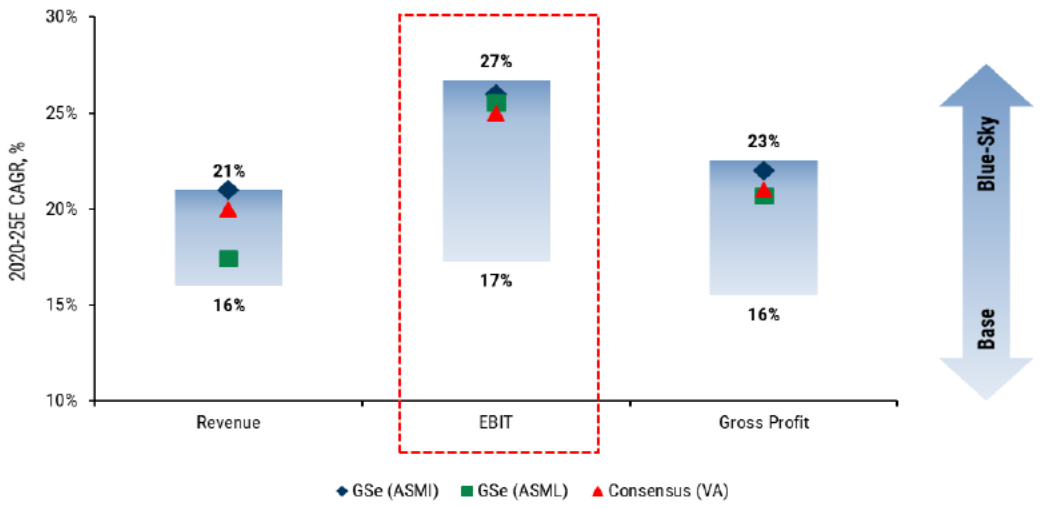
Source: Goldman Sachs Global Investment Research

As far as market share is concerned, ASMI sees **potential for long-term growth** driven by **increasing demand in leading-edge nodes** and expects strong performance in its single-layer ALD and Epitaxy business. We expect **ASMI to gain market share in both ALD and Epitaxy** and **project revenues of €3.5bn in FY25** implying a revenue **CAGR of 19%** since 2021 (assuming the upper end of the company's TAM estimates of $3.1bn-$3.7bn for ALD and $1.5bn-$1.8bn for Epitaxy). This compares with the company's target range of FY25 revenue of **€2.8-€3.4bn, implying a CAGR of 13%-19% since 2021.**

ASMI also expects **SG&A and net R&D expense to decline** over time resulting in **operating margin expansion with FY25 guidance of 26%-31% vs 28% in FY21**. We forecast margins in FY25 of 30%.

We compare in the exhibit below ASMI's revenue/EBIT growth vs. European peer ASML. Note that ASML operates in the lithography market, not deposition, but is a leading semicap player and therefore we include it for comparison. We additionally include ASMI's official base and blue-sky scenario targets. As seen below, our forecasts are significantly above base targets.

Exhibit 53: We see scope for ASMI to achieve a 21%/26% revenue/EBIT CAGR (2020-25E)
GSe vs. guidance



NB: Blue-sky scenario figures from ASMI and consensus data from Visible Alpha Consensus Data

Source: ASM International, Goldman Sachs Global Investment Research, Visible Alpha Consensus Data

We note that **our revenue/EBIT estimates** are **broadly in line with consensus for FY22/23** but are **higher in the *medium to longer term***. As such**,** our **FY24/25 revenue estimates are ahead of consensus by 4%/6%,** respectively, **driven by our more positive view on demand** drivers such as **leading-edge node shrinkage** and the **transition to Gate-All-Around architecture**. Our **EBIT estimates benefit from higher revenues** and improving operating leverage, **implying we are +5%/+7% above consensus**.

Exhibit 54: GSe ahead by 4%/6% on FY24/25 revenue
GSe vs consensus

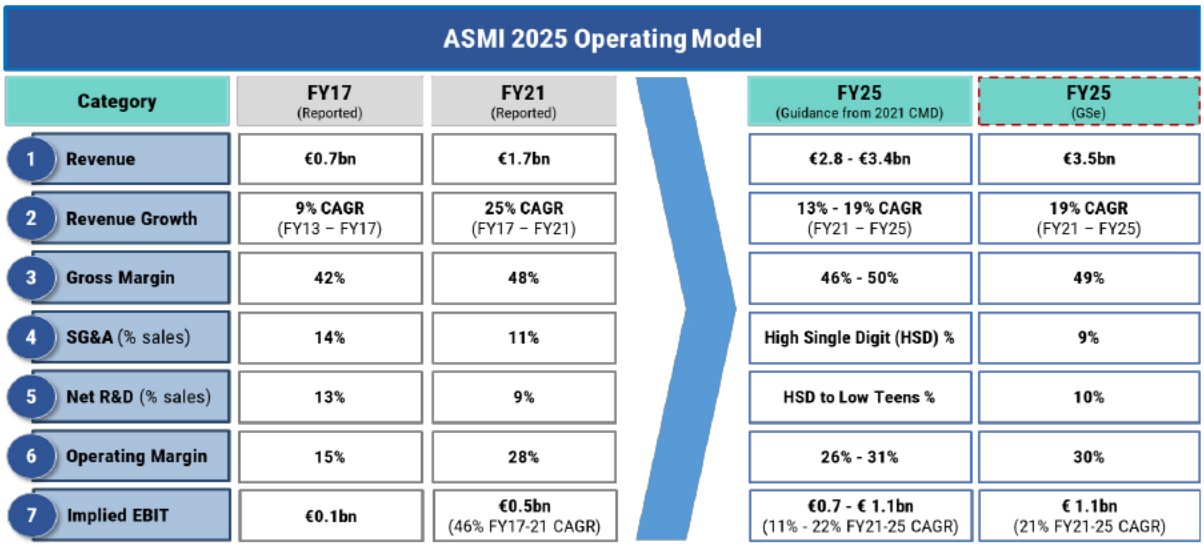
GS vs Consensus	3Q22			4Q22			FY22			FY23			FY24			FY25		
	GS	Cons	Delta %	GS	Cons	Delta %	GS	Cons	Delta %	GS	Cons	Delta %	GS	Cons	Delta %	GS	Cons	Delta %
Total revenue	**587**	**585**	**0%**	**609**	**610**	**0%**	**2,272**	**2,272**	**0%**	**2,616**	**2,597**	**1%**	**3,056**	**2,951**	**4%**	**3,509**	**3,320**	**6%**
% chg yoy	*36%*	*35%*		*24%*	*24%*		*31%*	*31%*		*15%*	*14%*		*17%*	*14%*		*15%*	*13%*	
% chg qoq	5%	5%		4%	4%													
Gross profit	**282**	**278**	**2%**	**295**	**290**	**1%**	**1,090**	**1,081**	**1%**	**1,269**	**1,241**	**2%**	**1,497**	**1,422**	**5%**	**1,733**	**1,629**	**6%**
% margin	*48.0%*	*47.5%*		*48.4%*	*47.5%*		*48.0%*	*47.6%*		*48.5%*	*47.8%*		*49.0%*	*48.2%*		*49.4%*	*49.1%*	
Operating result	**155**	**155**	**0%**	**162**	**160**	**1%**	**607**	**605**	**0%**	**739**	**719**	**3%**	**895**	**855**	**5%**	**1,060**	**992**	**7%**
% margin	*26%*	*26%*		*27%*	*26%*		*27%*	*27%*		*28%*	*28%*		*29%*	*29%*		*30%*	*30%*	
Normalized net earnings	142	149	-4%	146	144	1%	591	602	-2%	666	666	0%	808	779	4%	931	889	5%
% revenue	*24%*	*25%*		*24%*	*24%*		*26%*	*26%*		*25%*	*26%*		*26%*	*26%*		*27%*	*27%*	
EPS (recurring)	**2.91**	**2.98**	**-2%**	**2.98**	**2.88**	**3%**	**12.08**	**12.04**	**0%**	**13.64**	**13.42**	**2%**	**16.62**	**15.86**	**5%**	**19.27**	**18.27**	**5%**

Source: Goldman Sachs Global Investment Research, Visible Alpha Consensus Data

The company has significantly **improved its operating margin profile** by undertaking **multiple efficiency programmes** and guides for a **margin range of 26%-31% in FY25**. We see **efficiency programmes such as the reshoring of its supply base to Asia** as a positive and believe that the company is on track to **achieve its margin targets,** and hence **forecast a FY25 operating margin of 30%**.

Exhibit 55: Our estimates are at the top end of ASMI's targets, which envisage strong multi-year double-digit sales growth, with expanding margins

ASMI 2025 operating model



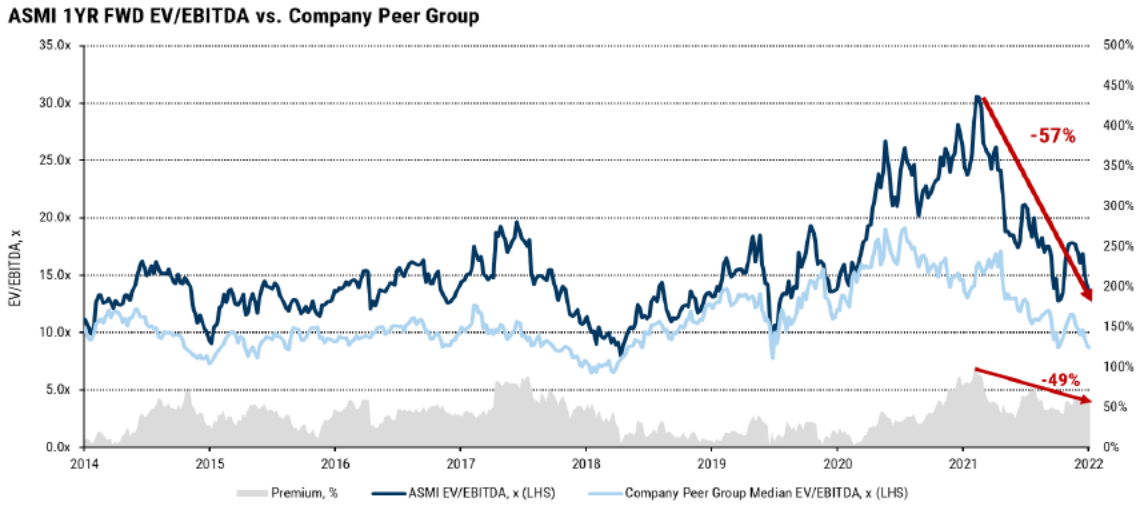
ASMI 2025 Operating Model					
Category	FY17 (Reported)	FY21 (Reported)		FY25 (Guidance from 2021 CMD)	FY25 (GSe)
1 Revenue	€0.7bn	€1.7bn		€2.8 - €3.4bn	€3.5bn
2 Revenue Growth	9% CAGR (FY13 – FY17)	25% CAGR (FY17 – FY21)		13% - 19% CAGR (FY21 – FY25)	19% CAGR (FY21 – FY25)
3 Gross Margin	42%	48%		46% - 50%	49%
4 SG&A (% sales)	14%	11%		High Single Digit (HSD) %	9%
5 Net R&D (% sales)	13%	9%		HSD to Low Teens %	10%
6 Operating Margin	15%	28%		26% - 31%	30%
7 Implied EBIT	€0.1bn	€0.5bn (46% FY17-21 CAGR)		€0.7 - € 1.1bn (11% - 22% FY21-25 CAGR)	€ 1.1bn (21% FY21-25 CAGR)

Source: Goldman Sachs Global Investment Research, Company data

ASMI warrants a valuation multiple premium given its significantly higher growth vs peers

While ASMI's shares are up 91%/177% in the last two/three years (vs Europe Tech -16%/-2%), we note that the stock has de-rated by 57% since its peak on 1-year forward EV/EBITDA. Furthermore, we believe that the current trading multiple does not fully reflect the longevity of growth offered by the company compared with its global semicap equipment peer group. In particular, we note that ASMI, on our estimates, offers a revenue CAGR in 2021-24 of 21%, which is 57% higher than that of peers in absolute terms. Meanwhile, it trades at an EV/EBITDA multiple of 12x, implying a premium of only 9% vs its peers (peers at 11x) on 2023E. As such, our 12-month price target of €365 is based on 19x EV/EBITDA applied to 2023E, as we believe ASMI warrants a premium vs peers given our growth expectations. We also cross-check valuation against history to see what the change in multiple premium/discount vs. peers looks like in the context of the delta in growth vs competitors.

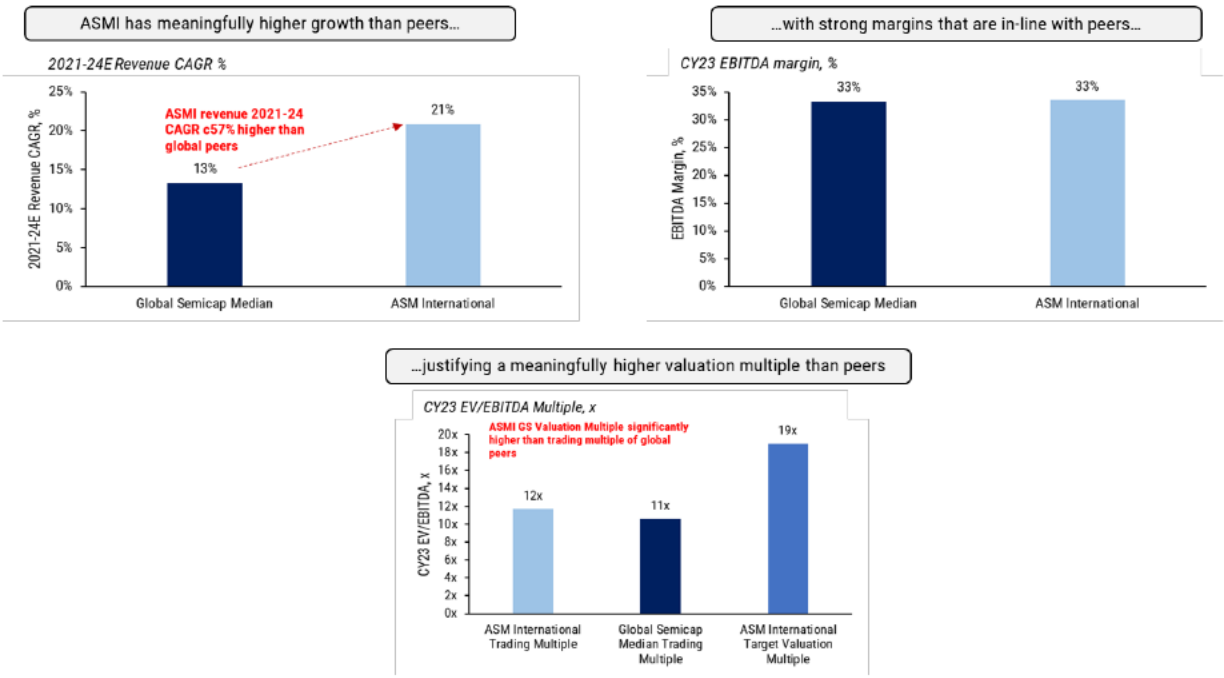
Exhibit 56: ASMI has recently seen a 57% de-rating in terms of 1-year forward EV/EBITDA



*Company peer group includes direct semicap players: AMAT, ASML, KLA, LAM, and TEL. Based on consensus data.

Source: Goldman Sachs Global Investment Research, Eikon Datastream

Exhibit 57: Our ASMI 12m PT is based on a 72% premium to the current global peer median owing to our expectation of a 57% higher 2021-24 revenue growth CAGR and similar EBITDA margins



Global semicap peers include: ASML, Applied Materials, Lam Research, KLA, Tokyo Electron, Entegris, Teradyne, Advantest, HOYA, Ulvac

Source: Goldman Sachs Global Investment Research

We also cross-check our valuation approach in the context of history and believe that the expansion in growth relative to the sector that we expect for ASMI is not yet reflected in its valuation premium to the sector. We note that while ASMI has typically traded at a 39% premium on 1Y forward EV/EBITDA vs global semicap equipment peers (in the last eight years), it is now on a 53% premium, i.e. 1.3x higher.

However, we believe this understates the expansion in relative growth we forecast. In particular, ASMI historically saw 3Y forward revenue growth that was 1.4x its global semicap peer average, but we see this expanding to 3.3x now, which is 2.4x higher.

Exhibit 58: The expansion we see in the delta of ASMI's 3Y forward revenue CAGR vs. the sector is not adequately reflected in the current delta of 1Y forward EV/EBITDA vs the sector average, in our view

		Trading Multiples		
		1Y FWD EV/EBITDA		
		Historical Average (8Y)	Current	*Delta*
ASMI Premium/Discount	Vs. Global Semicap Peers	39%	53%	*1.3x*
	Vs. SOXX Index	31%	35%	*1.1x*

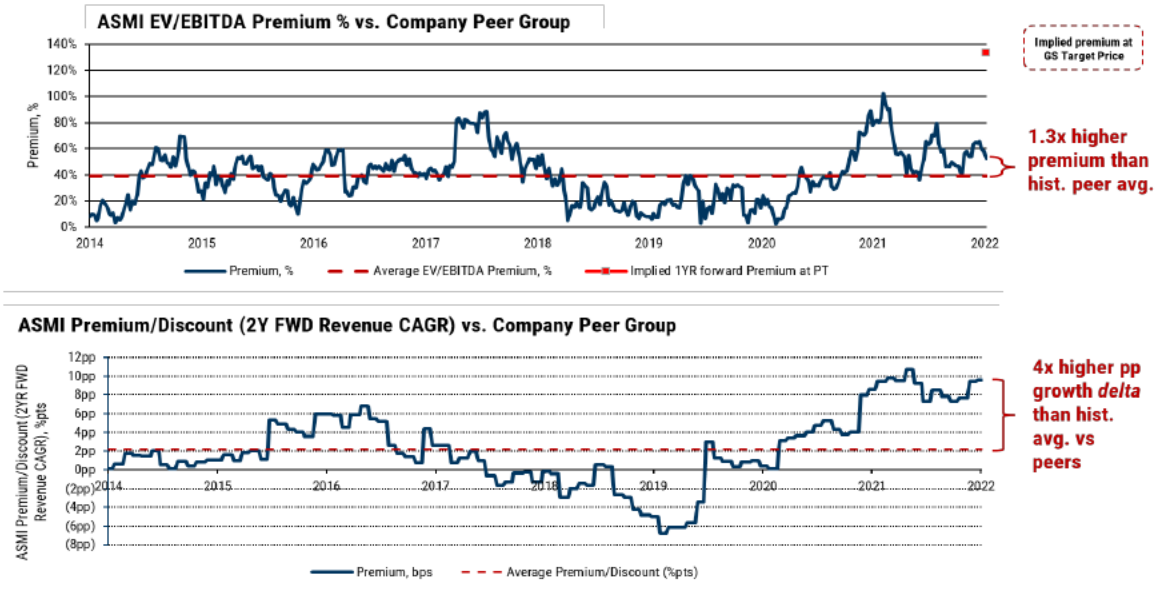
		Key Performance Indicators		
		3Y FWD Revenue CAGR		
		Historical Average (8Y)	Current	*Delta*
ASMI Premium/Discount	Vs. Global Semicap Peers	1.4x	3.3x	*2.4x*
	Vs. SOXX Index	1.4x	2.2x	*1.5x*

		Key Performance Indicators		
		1Y FWD EBIT Margins		
		Historical Average (8Y)	Current	*Delta*
ASMI Premium/Discount	Vs. Global Semicap Peers	0.7x	0.8x	*1.1x*
	Vs. SOXX Index	0.8x	0.8x	*1.1x*

3Y forward data for peers and 1Y forward multiples from consensus

Source: Goldman Sachs Global Investment Research, Eikon Datastream

Exhibit 59: Our target multiple therefore implies a >2x expansion in premium to global semicap peers vs history



Company peer group includes direct semicap players: AMAT, ASML, KLA, LAM, and TEL. Based on consensus data.

Source: Eikon Datastream, Goldman Sachs Global Investment Research

Downside scenario suggests a positive risk-reward skew relative to our coverage

Given the fluid macroeconomic environment, we include a downside scenario analysis and conclude that ASMI has a favourable risk-reward relative to our Europe Technology Hardware coverage as summarised in the exhibits below. Overall, we see roughly 3x upside to our 12m PT vs the downside implied by our downside scenario.

In our scenario analysis, we see the **greatest risk** from a **macroeconomic downturn** in **ASMI's exposure to lagging-edge nodes and memory segments**. That said, we believe that **ASMI's limited exposure to both lagging-edge nodes and memory demand**, coupled with its **high share in leading-edge logic/foundry nodes** and the importance of ALD and Epitaxy in technology transitions, **means that the company is relatively less sensitive to short-term cyclical swings** owing to continuous investment in capex by leading-edge semiconductor manufacturers. Nevertheless, our downside scenario stress tests potential declines in revenue in a less favourable macro environment than we currently forecast with reference to historical declines in such circumstances.

As such, in our downside case, we assume a **front-end equipment revenue decline of around 13%** (in line with the decline in revenues in previous downturns), with spares and services revenues also declining by 13% (as these revenues are correlated with front-end revenues). We observed that the company maintained an **operating leverage of around 40%** in previous downturns and hence **we assume an EBIT margin compression of 1pp**, **impacted negatively by reduced revenue in a tough macro environment and higher inflationary costs**.

ASMI trades at a premium of 31% to our broader EU Tech coverage. In our downside case, we assume **a multiple of 12x EV/EBITDA**, implying a **premium of only 17%** to the sector. This is in line with the 10Y median premium to EU Tech. We believe such a multiple would be conservative as it would give ASMI very little credit for its growth that is expected to be significantly higher than that of the sector over the next 3-4 years and its positioning having improved with a higher share in increasingly important technologies such as ALD and Epitaxy. Based on the valuation multiple, **we see a downside of about 18% to the current market price.** Given this, the **stock screens favourably relative to our coverage with a positive risk-reward skew of 3x based on the upside to our 12m PT.**

Exhibit 60: In our downside scenario, we assume a contraction in revenues similar to what ASMI saw on average in prior downturns and assume downside operating leverage congruent with historical downcycle patterns

Company	ASM INTERNATIONAL — BUY
Historic precedent	▪ Global **WFE Market declined** -22%/-76%/-43%/-22%/-21% peak-to-trough in last 5 downcycles **(average of -37%)** ▪ ASMI declined average of **-13% in prior downturns** (due to **high leading-edge revenue exposure**, which is **more resilient than lagging-edge** in our view)
Macro-sensitive exposures	▪ We assume that **all product lines could be affected by extreme macro-shocks**, but expect **leading-edge players continue to spend on tech transitions** in base case ▪ **Single-wafer ALD and Epitaxy are leading-edge technologies** that are necessary for **upcoming advanced node transitions**
Impact from higher interest rates	▪ NA
Input costs vs pricing power	▪ **Limited pricing power** due to concentrated customer base . ▪ Some ability to **pass through higher input costs**
Downside scenario impact on sales	▪ **No change** to **FY22** estimates given **strong backlog / customer demand** ▪ We assume **front-end equipment** (e.g. ALD and Epitaxy) **decline by 13% in FY23** (in line with average historic decline in downturns for ASMI) ▪ We assume **Spares and Services revenues** are correlated with front end equipment revenues and hence **we assume a decline of 13% in FY23**
Downside scenario impact on margins	▪ We assume **margin compression of 1pp** in FY23 (based on **average historic operating leverage of c40%)** ▪ Group **operating margins impacted negatively by reduced topline** (albeit relatively high share of cost are variable) ▪ **Factor in higher R&D and SG&A costs** e.g. higher inflation

Source: Goldman Sachs Global Investment Research

Exhibit 61: We see 18% downside in a downside scenario as per our analysis, but see a risk-reward skew of 3x based on upside to our 12m PT

Company	ASMI Buy
Valuation Methology	EV/EBITDA
Current Trading Premium / Discount to EU Tech (on cons ests.) *	31%
10Y Premium/Discount to EU Tech (on cons ests.) *	17%
Current Valuation PT Multiple (applied to base-case)	19x
Downside Scenario Valuation Multiple (applied to downside scenario)	12x
Delta	-39%
Current FY22/23 Sales Growth Ests.	31% / 15%
Downside scenario FY22/23 Sales Growth Ests.	31% / -13%
Current FY22/23 Revenue Ests.	Revenue (€mn): 2,272 / 2,616
Downside scenario FY22/23 Revenue Ests.	Revenue (€mn): 2,272 / 1,977
Delta	0% / -24%
Delta vs Cons FY22/23 (Base case)	0% / 1%
Delta vs Cons FY22/23 (downside scenario)	0% / -24%
Current FY22/23 Ests. Used for Valuation	EBITDA (€mn): 716 / 870
Downside scenario FY22/23 Ests. Used for Valuation	EBITDA (€mn): 716 / 665
Delta	0% / -24%
Delta vs Cons FY22/23 (Base case)	0% / 3%
Delta vs Cons FY22/23 (downside scenario)	0% /-21%
Current PT / Upside or Downside	€365 / 57%
Downside Scenario Implied Valuation / Upside or Downside	€183 / -18%
CY23 Multiple at PT (on base-case ests.)	19x
Implied CY23 Multiple at downside implied val. (on downside scenario ests.)	12x
Trading CY23 Multiple base -case ests.)	12x
Trading CY23 Multiple (on downside scenario ests.)	15x

*1Y forward EV/EBITDA

Source: Goldman Sachs Global Investment Research, Eikon Datastream, Visible Alpha Consensus Data

Key downside risks to our estimates and price target include slower adoption of technology, an unfavourable macro outlook and increased competition resulting in market share erosion

There are various factors that could affect ASMI's growth in the coming years. The key risks include:

- Given the weakness in consumer and memory end markets, a **cyclical downturn** is one of the risks that ASMI is facing. There is also a risk of **customers cancelling/pushing out orders** if the cycle deteriorates. In this regard, we note the company's **exposure to leading-edge logic/foundry and its strong backlog**.
- Furthermore, ASMI **already has a large market share in ALD and considerably lower absolute R&D spend** compared to that of its key competitors like AMAT and LAM; if this poses a challenge in maintaining its growth rate, it may impact our estimates.
- We also note that ASMI's **high customer concentration** could result in **lower pricing power or potentially lead to more variability in demand.**
- Lastly, **higher competition from larger incumbent players in an adjacent market**

to ALD (i.e. Epitaxy) could pose a risk. We note that Epitaxy is a somewhat niche technology for very specific applications whereas ALD relies on mastery of a broad platform, making it challenging to perfect.

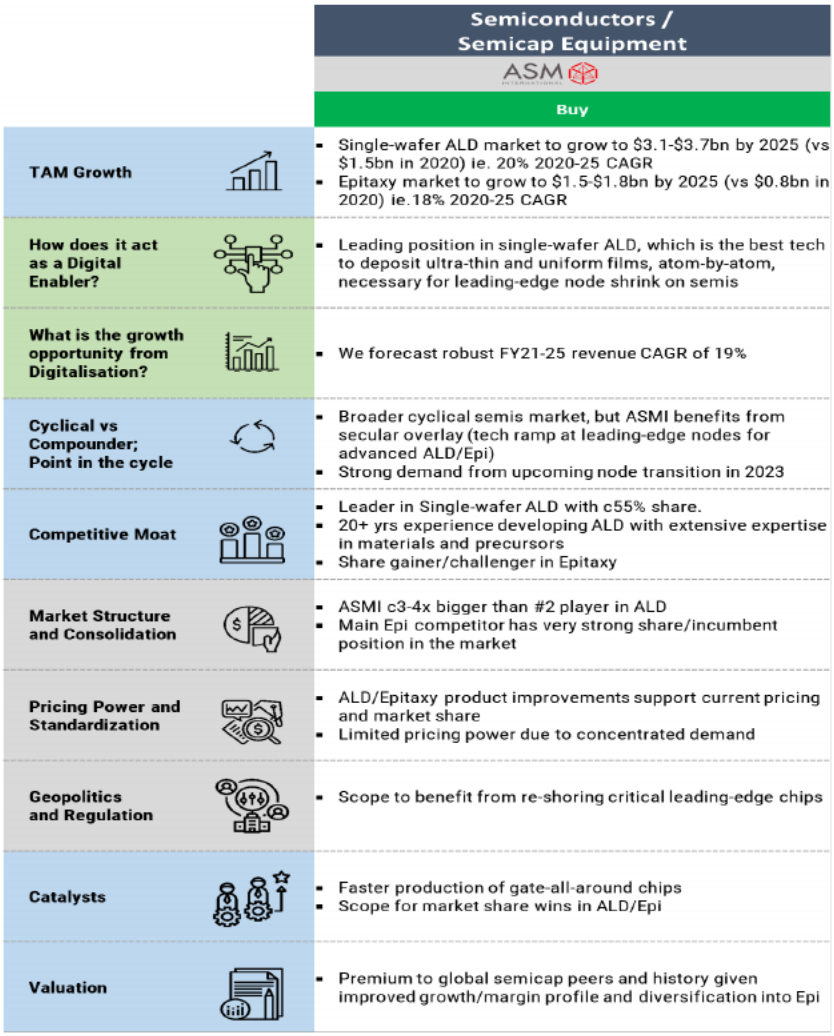
Exhibit 62: Key risks include cyclicality, customer concentration, and R&D spending capacity vs. rivals
Key risks for ASMI

	1	2	3	4	5	6
	Cyclicality	Customer Concentration	R&D Capacity vs. Competitors	Higher competition	Large share in core market	Order Delays
Key Risks	The cyclicality of the semiconductor market could result in fixed overheads weighing on margins during downturns; Weak consumer/Memory datapoints already manifesting	High dependence on a few customers (top 3 customers account for 59% of ASMI's revenues) could reduce pricing power, or potentially lead to more variability in demand	ASMI's total R&D (€206mn for FY21) is considerably lower than some of its key competitors AMAT (c€2.5bn*) and Lam (c€1.5bn*)	Large incumbent player (AMAT) in an adjacent market to ALD (i.e. Epitaxy) could add competitive risks	With 55% share in single-wafer ALD, ASMI may find it increasingly difficult to maintain its revenue/EPS growth CAGR of 22%/25% (2016-20), which could lead to a de-rating of its trading multiples	Risk of order cancellations/push-out if semis cycle deteriorates materially. GS forecasts -17% WFE revenues in 2023.
Potential Mitigants	ASMI more exposed to leading-edge Logic/Foundry than lagging-edge or Memory ie. fastest growing portion of market	High customer concentration in industry (top 3 customers for peer LAM are 47% of revenues); ASMI diversifying into Epitaxy	ASMI has already expanded Epi share with large customer and recently won 2nd key Epi customer; ASMI continues to expand its patent portfolio (+41% vs. 2016)	Epitaxy is used for very niche specific applications, while ALD is a broad platform (i.e. harder to develop). ASMI has 20+ years experience with ALD	Large share gain opportunity remains in Epitaxy, driven primarily by advanced Logic use cases (e.g. building the transistor channel for GAA), with evidence of wins hitherto	ASMI has strong order backlog of €1,408mn (we est. covers 2-3 quarters), which provides buffer if order delay risks materialise. ASMI also focuses on leading-edge nodes, which we believe are more resilient to macro shocks.

*At EUR/US$ of 1.14

Source: Goldman Sachs Global Investment Research, Company data

Exhibit 63: Digital Enablers Framework: ASMI (Buy)



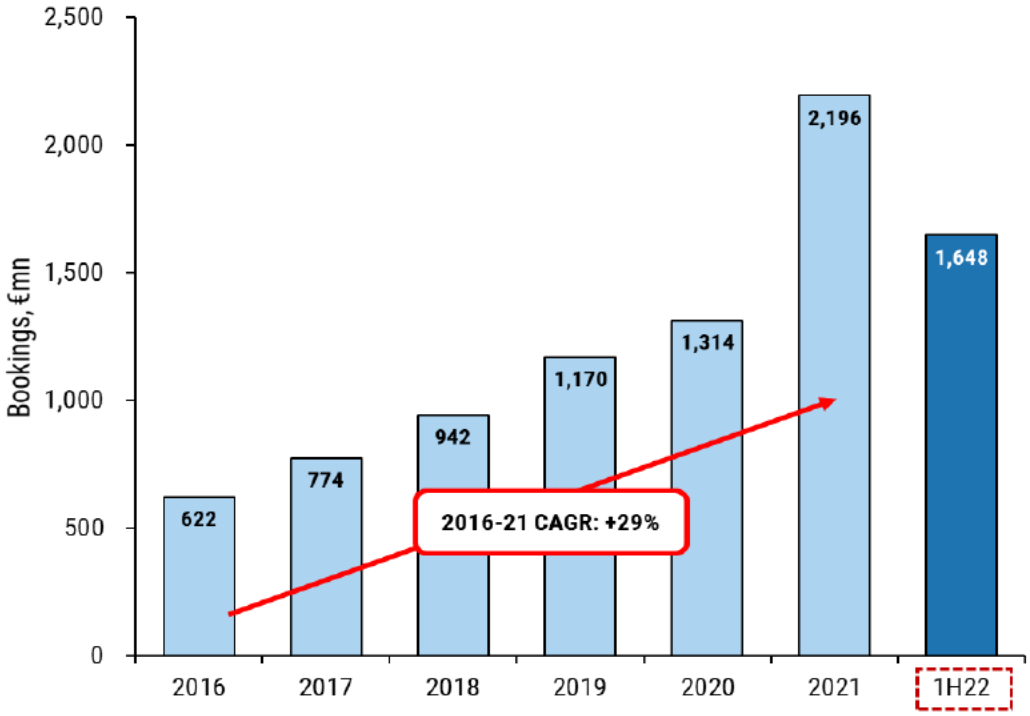
Source: ASM International (TAM estimates), Goldman Sachs Global Investment Research

Appendix

ASMI's bookings growth has been strong, underpinning future revenue growth

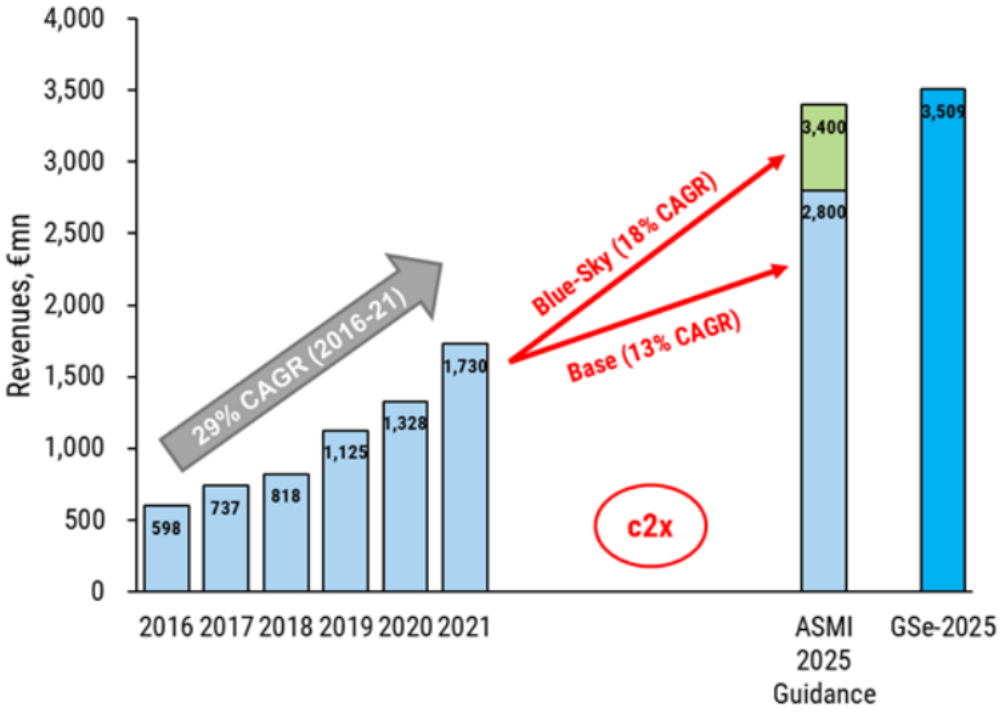
ASMI saw a bookings CAGR of 29% during 2016-20, and recorded bookings of €2.2bn in 2021. We note that revenues have grown broadly at the same pace during the last five years (29% CAGR), with ASMI recording revenues of €1.7bn in 2021. This supports our expectation of strong revenue growth, with expected revenues of $3.5bn in 2025, implying a CAGR of 19% from 2021-25.

Exhibit 64: Bookings recorded a 2016-20 CAGR of 29%, reaching €2.2bn in 2021…
ASMI group bookings, €mn



Source: ASM International, Goldman Sachs Global Investment Research

Exhibit 65: …while revenues have grown at broadly the same pace over the last five years and are set to expand rapidly in coming years
ASMI group revenues, €mn



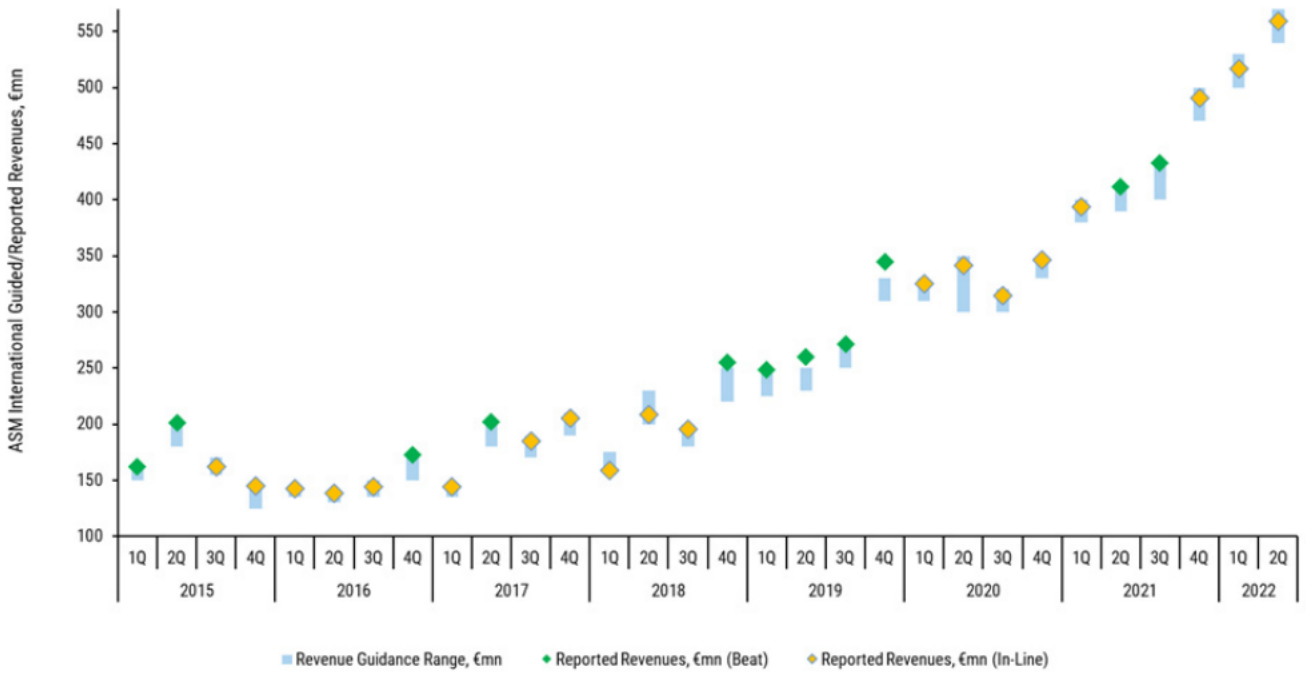
NB: Blue-sky scenario according to ASMI

Source: Company data, Goldman Sachs Global Investment Research

ASMI's execution over the last 7-8 years has been strong

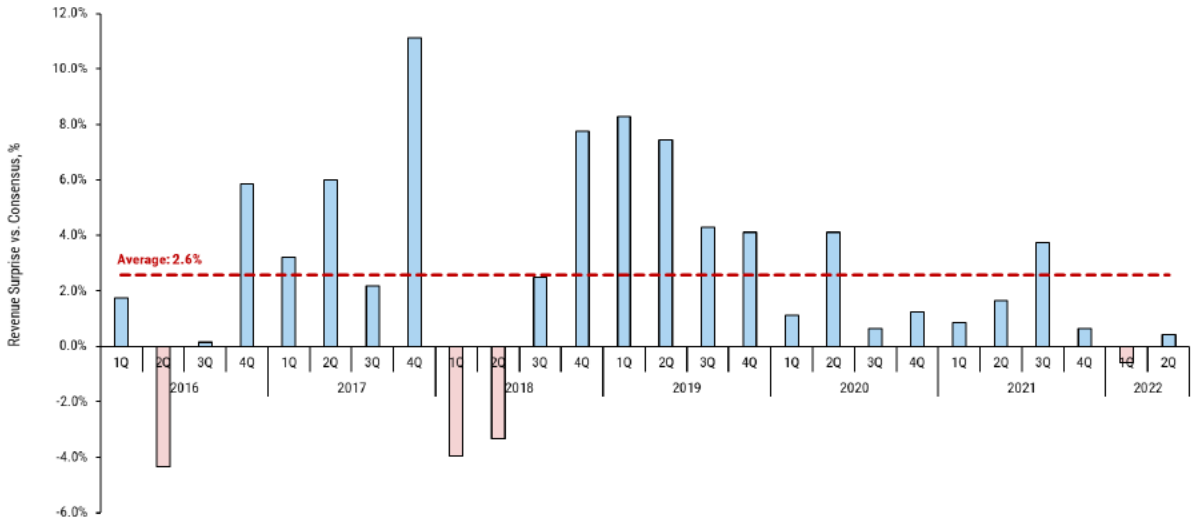
Since 2015, ASMI has not reported below its revenue guidance, while the company has only missed consensus estimates four times in the last 22 quarters.

Exhibit 66: Since 2015, ASMI has not reported revenues below its guided sales range…
ASMI quarterly revenue surprise vs. guidance



Source: Goldman Sachs Global Investment Research, Company data

Exhibit 67: …while missing consensus expectations only four times in the last 22 quarters
ASMI's quarterly revenue surprise vs. consensus



Source: Company data, Refinitiv Eikon

We see shipment of evaluation tools as a leading indicator of sales for ASMI and see current strong levels pointing to continued strong growth in revenues in coming years.

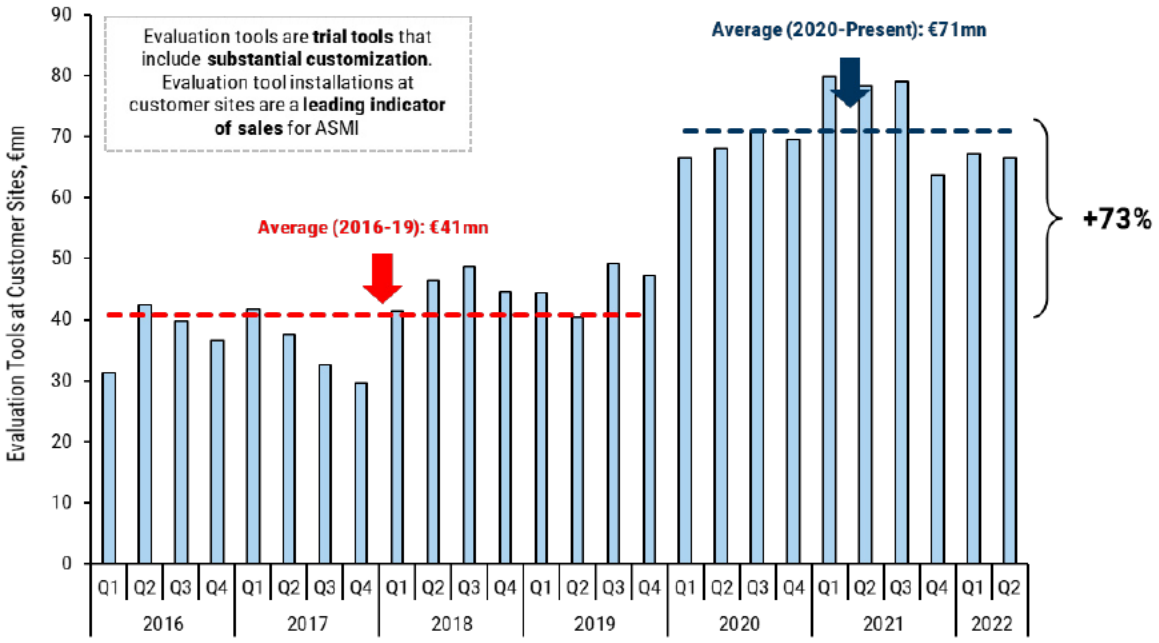
Exhibit 68: Evaluation tools are leading indicators of revenue and new applications at smaller process nodes
Overview of evaluation tools

Overview of Evaluation Tools	
Evaluation tools…	Commentary
What are evaluation tools?	• Evaluation tools are tools delivered to customers but remain under evaluation (similar to a trial period) • Only installed for novel applications (as opposed to existing/mature ones) • Majority of evaluation tools shipped to customers result in final sale of the tool.
Evaluation tools as revenue indicators	• We see build-up of eval. tools as a leading indicator of revenue and new applications at future smaller nodes • That said, ASMI can still sell tools to customers ***without*** a trial period (and hence no evaluation tool)
Evaluation tools' impact on gross margins	• Evaluation tools placed with customers are recorded at cost and depreciated straight-line over 5Y in COGS • Therefore, growth in evaluation tools could potentially lower GMs at a group level • After completion of the trial period, ASMI sells the evaluation tool to the customer, which (per ASMI) can occur at lower GMs at a tool level due to customizations and last-minute changes • However, we note that **once ASMI's tools enter high**-volume manufacturing (which occurs once the yield at customer sites improves), subsequent tools will be sold at commercial prices/margins

Source: Company data, Goldman Sachs Global Investment Research

The value of evaluation tools at customer sites has increased from €41mn (average during 2016-19) to €71mn (since 2020), implying a 73% increase, meaning that shipments of evaluation tools result in the sale of tools in the majority of cases.

Exhibit 69: The majority of evaluation tools shipped by ASMI to customers result in the sale of the tool, per the company, and the current average level of tool sales is significantly above pre-2019 average levels
ASMI evaluation tools at customer sites, €mn



Source: Company data, Goldman Sachs Global Investment Research

Spares and services model in the process of being shifted to a more outcome-based model, to achieve more recurring-type revenues in this segment

In recent years, ASMI has started to shift its spares and services business from a transaction service model (meaning if a tool breaks down, the company would fix it and provide the necessary spare parts when needed) to an outcome-based model and spares-as-a-service offering, where ASMI provides solutions such as predictive maintenance and takes more responsibility for providing spare parts.

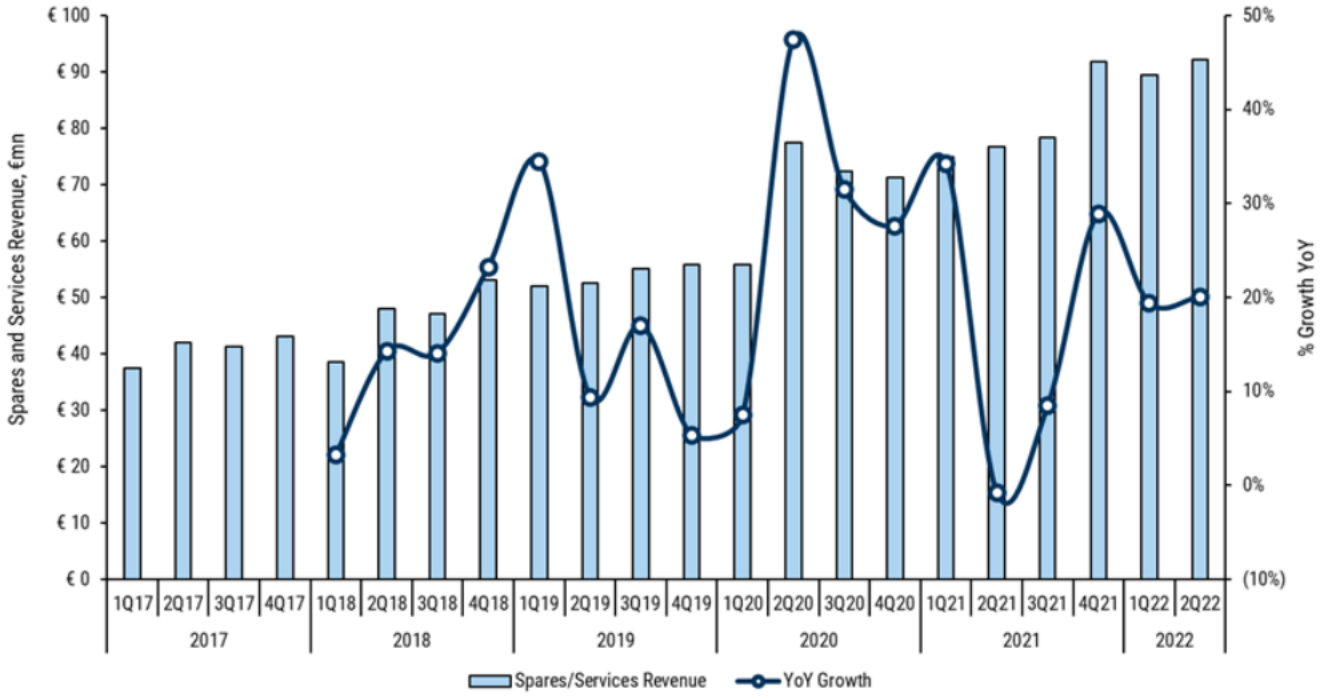
Exhibit 70: The spares and services business has shown healthy growth, driven by new services such as predictive maintenance and an expanding installed base
Overview of ASMI's spares and services business

Overview of ASMI's Spares and Services Business	
Model	Commentary
Old Model: Break-and-Fix	• Up until c.2 years ago, the **main driver of the Spares/Services business was ASMI's installed base** • ASMI offered a transaction service model, whereby if a tool broke down, the company would fix it, as well as providing spare parts where necessary
New Model: Outcome-Based	• ASMI booked multiple contracts for outcome-based services and spares-as-a-service offerings in 2021 • This offering includes services such as predictive maintenance, as well as for ASMI to take more responsibility for providing spare parts
Implications	• We believe subscription contracts enable lower cost of ownership for customers and increased uptime • We see ASMI in the early innings of the transition away from the break-and-fix model, with further healthy growth in 2022

Source: Company data, Goldman Sachs Global Investment Research

We believe the transition of the spares and services business away from the break-and-fix model will support group revenue in 2022 and beyond through an expansion of the company's installed base.

Exhibit 71: ASMI's spares and services business supports group revenue growth through an expansion of the company's installed base
LHS: ASMI spares and services revenue, €mn | RHS: YoY growth, %

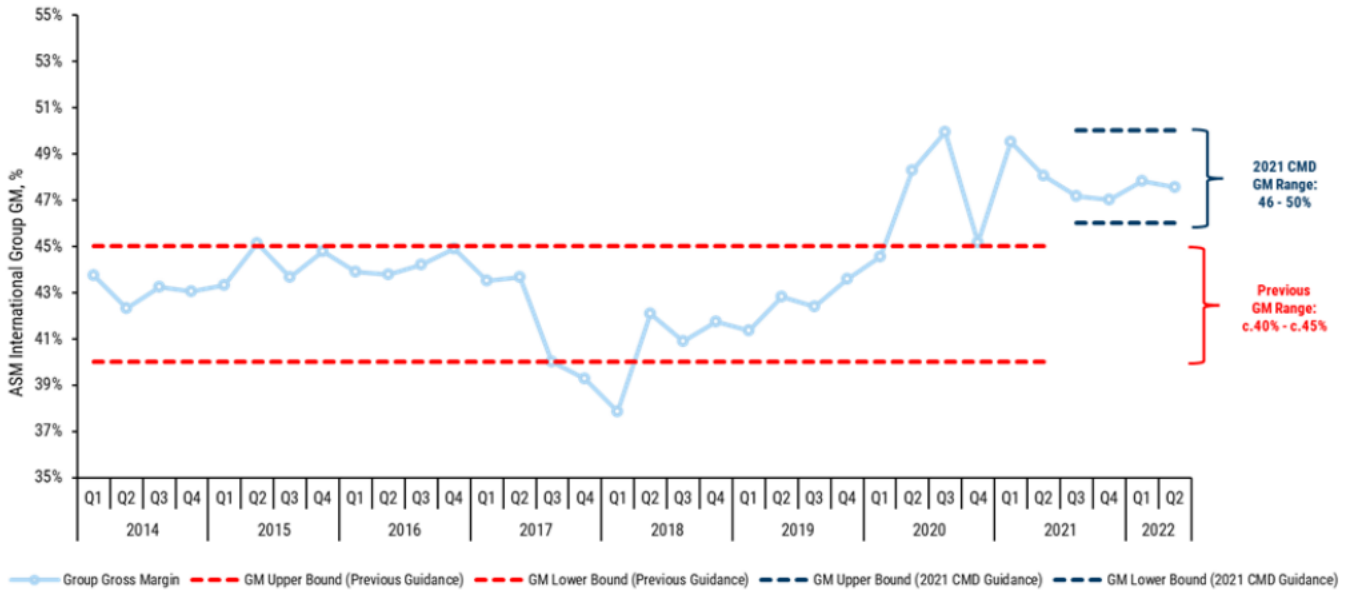


Source: Company data, Goldman Sachs Global Investment Research

We expect further EBIT margin expansion based on gross margins rising and top-line leverage

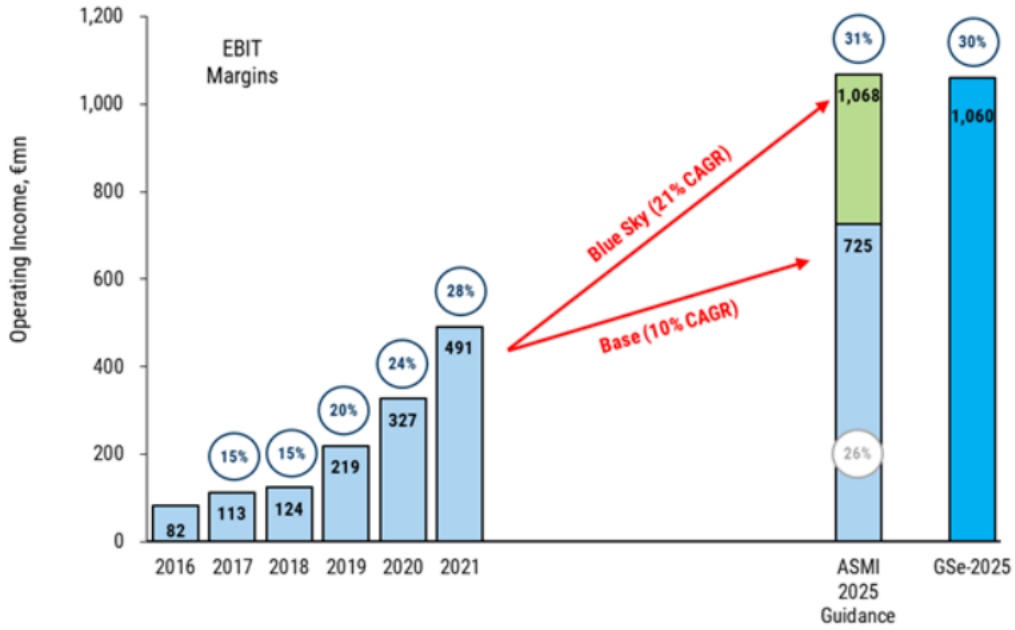
ASMI significantly raised its 2025 GM guidance to 46%-50% at the time of its 2021 CMD, from c.40%-c.45% previously, which reflects a focus on better cost efficiency and productivity improvements.

Exhibit 72: Raised GM guidance reflects a focus on productivity improvements and operating leverage…
ASMI group gross margins, %



Source: Company data, Goldman Sachs Global Investment Research

Exhibit 73: …while ASMI's EBIT has grown over 40% p.a. since 2016
ASMI group operating income, €mn



NB: Blue-sky scenario according to ASMI

Source: Company data, Goldman Sachs Global Investment Research

Exhibit 74: ASM International profit and loss statement highlights consistent growth in revenue and EBIT with revenue/EBIT CAGRs of 18%/20% across 2021-26E

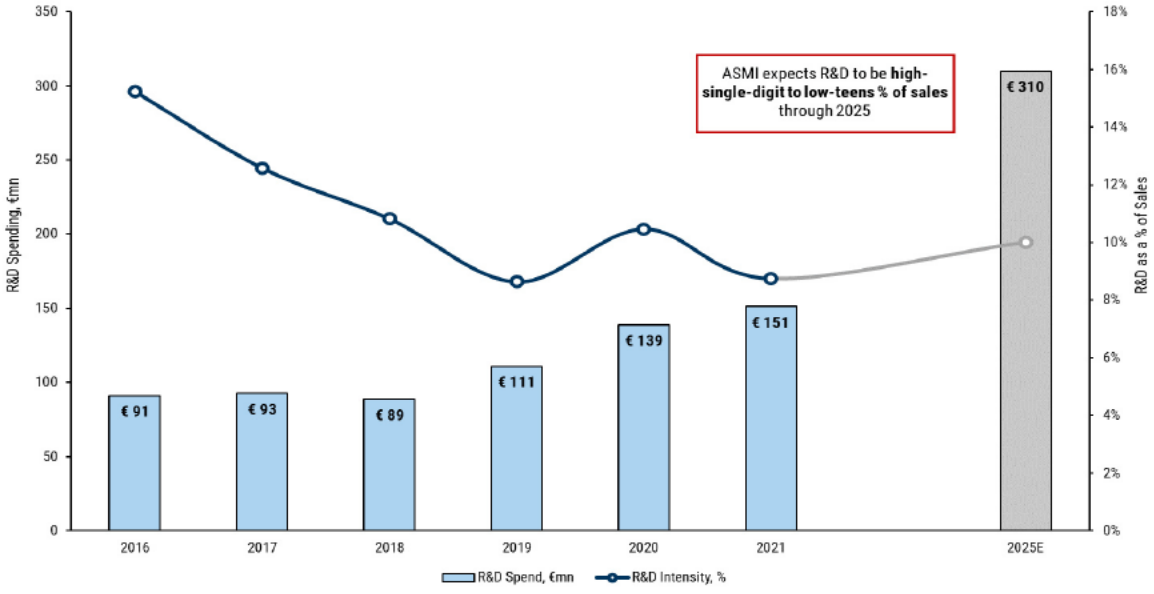
ASM International

Fiscal Year Ends Dec	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022E	2023E	2024E	2025E	2026E
Income Statement															
(Euros in millions, US GAAP)															
Revenues	1,418.1	612.3	545.6	669.6	597.9	737.4	818.1	1,283.9	1,328.1	1,729.9	2,272.2	2,615.6	3,055.7	3,508.9	3,961.4
Sequential change	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Year-over-year change	*-13.2%*	*-56.8%*	*-10.9%*	*22.7%*	*-10.7%*	*23.3%*	*10.9%*	*56.9%*	*3.4%*	*30.3%*	*31.3%*	*15.1%*	*16.8%*	*14.8%*	*12.9%*
Cost of good sold	977.6	397.8	310.5	373.3	333.4	431.5	483.8	645.4	704.6	901.8	1,182.7	1,347.0	1,558.4	1,775.5	1,980.7
Percent of revenues	*68.9%*	*65.0%*	*56.9%*	*55.7%*	*55.8%*	*58.5%*	*59.1%*	*50.3%*	*53.0%*	*52.1%*	*52.1%*	*51.5%*	*51.0%*	*50.6%*	*50.0%*
Gross Profit	440.4	214.5	235.0	296.3	264.5	305.9	334.3	638.5	623.6	828.1	1,089.5	1,268.6	1,497.3	1,733.4	1,980.7
Gross margin	31.1%	35.0%	43.1%	44.3%	44.2%	41.5%	40.9%	49.7%	47.0%	47.9%	48.0%	48.5%	49.0%	49.4%	50.0%
Selling, general and administrative	202.1	96.3	80.5	93.0	88.0	99.2	121.3	148.8	157.4	189.5	272.2	287.7	311.7	329.8	356.5
Percent of revenues	14.2%	15.7%	14.8%	13.9%	14.7%	13.4%	14.8%	11.6%	11.8%	11.0%	12.0%	11.0%	10.2%	9.4%	9.0%
Research & Development	149.2	75.4	63.8	95.3	91.1	92.8	88.6	110.8	139.0	151.2	210.4	241.9	290.3	343.9	380.3
Percent of revenues	10.5%	12.3%	11.7%	14.2%	15.2%	12.6%	10.8%	8.6%	10.5%	8.7%	9.3%	9.3%	9.5%	9.8%	9.6%
Total operating expenses	351.3	172.6	144.4	188.3	179.1	191.9	209.9	259.7	296.4	336.7	482.5	529.7	602.0	673.7	736.8
Percent of revenues	24.8%	28.2%	26.5%	28.1%	30.0%	26.0%	25.7%	20.2%	22.3%	19.5%	21.2%	20.3%	19.7%	19.2%	18.6%
Operating income	89.2	41.9	90.7	108.0	85.4	114.0	124.4	378.8	327.2	491.5	607.0	738.9	895.3	1,059.7	1,243.9
Percent of revenues	6.3%	6.8%	16.6%	16.1%	14.3%	15.5%	15.2%	29.5%	24.6%	28.4%	26.7%	28.3%	29.3%	30.2%	31.4%
Financial expense (income)	18.6	6.4	-9.0	6.4	-2.0	0.1	1.4	0.1	1.9	2.0	1.5	2.6	3.1	3.5	4.0
Percent of revenues	1.3%	1.1%	-1.7%	1.0%	-0.3%	0.0%	0.2%	0.0%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Other non-operating income (expense)	-0.8	-4.9	16.6	0.9	20.9	-31.3	1.1	-0.3	-23.2	33.5	35.5	0.0	0.0	0.0	0.0
Percent of revenues	-0.1%	-0.8%	3.0%	0.1%	3.5%	-4.2%	0.1%	0.0%	-1.7%	1.9%	1.6%	0.0%	0.0%	0.0%	0.0%
Earnings before taxes	69.8	30.6	116.3	102.5	108.3	82.5	124.1	378.4	302.1	522.9	641.0	736.3	892.3	1,056.2	1,239.9
Percent of revenues	4.9%	5.0%	21.3%	15.3%	18.1%	11.2%	15.2%	29.5%	22.7%	30.2%	28.2%	28.2%	29.2%	30.1%	31.3%
Taxes	26.3	9.0	17.6	-5.9	2.3	4.6	15.4	53.7	48.7	102.6	129.9	150.9	187.4	228.1	272.8
Tax rate	37.7%	29.3%	15.1%	-5.8%	2.1%	5.6%	12.4%	14.2%	16.1%	19.6%	20.3%	20.5%	21.0%	21.6%	22.0%
Minority (loss)/profit	-33.3	2.6	46.6	23.9	40.5	357.1	48.4	4.2	32.0	74.4	80.0	81.0	103.0	103.2	103.2
Percent of revenues	-2.3%	0.4%	8.5%	3.6%	6.8%	48.4%	5.9%	0.3%	2.4%	4.3%	3.5%	3.1%	3.4%	2.9%	2.6%
Net income (recurring)	10.2	27.1	134.4	125.7	146.5	435.0	157.1	329.0	285.4	494.7	591.1	666.4	807.9	931.2	1,070.3
Percent of revenues	0.7%	4.4%	24.6%	18.8%	24.5%	59.0%	19.2%	25.6%	21.5%	28.6%	26.0%	25.5%	26.4%	26.5%	27.0%
Net income (reported)	7.1	1,025.3	137.3	154.1	135.5	435.0	157.1	329.0	285.4	494.7	591.1	666.4	807.9	931.2	1,070.3
Percent of revenues	0.5%	167.4%	25.2%	23.0%	22.7%	59.0%	19.2%	25.6%	21.5%	28.6%	26.0%	25.5%	26.4%	26.5%	27.0%
EPS - reported	€ 0.13	€ 16.21	€ 2.12	€ 2.43	€ 2.22	€ 7.41	€ 2.97	€ 6.57	€ 5.78	€ 10.10	€ 12.08	€ 13.64	€ 16.62	€ 19.27	€ 22.31
EPS - extraordinary	-€ 0.06	€ 15.78	€ 0.04	€ 0.45	-€ 0.18	€ 0.00	€ 0.00	€ 0.00	€ 0.00	€ 0.00	€ 0.00	€ 0.00	€ 0.00	€ 0.00	€ 0.00
EPS - recurring	€ 0.18	€ 0.43	€ 2.08	€ 1.98	€ 2.39	€ 7.41	€ 2.97	€ 6.57	€ 5.78	€ 10.10	€ 12.08	€ 13.64	€ 16.62	€ 19.27	€ 22.31
Diluted Shares (millions)	56.1	63.2	64.6	63.3	61.3	59.6	53.7	50.1	49.4	49.0	48.9	48.8	48.6	48.3	48.0

Source: Company data, Goldman Sachs Global Investment Research

ASMI has maintained high R&D intensity in the last five years to develop its ALD/Epitaxy portfolio. It expects R&D intensity to decline to HSD to low-teens % of sales through 2025, implying a reduction in operating costs over time. The company has substantially expanded its production capacity through its newly completed South Korea and Singapore facilities and expects to spend €60-€100mn annually through 2025, implying a capex intensity of around 2.5% in 2025.

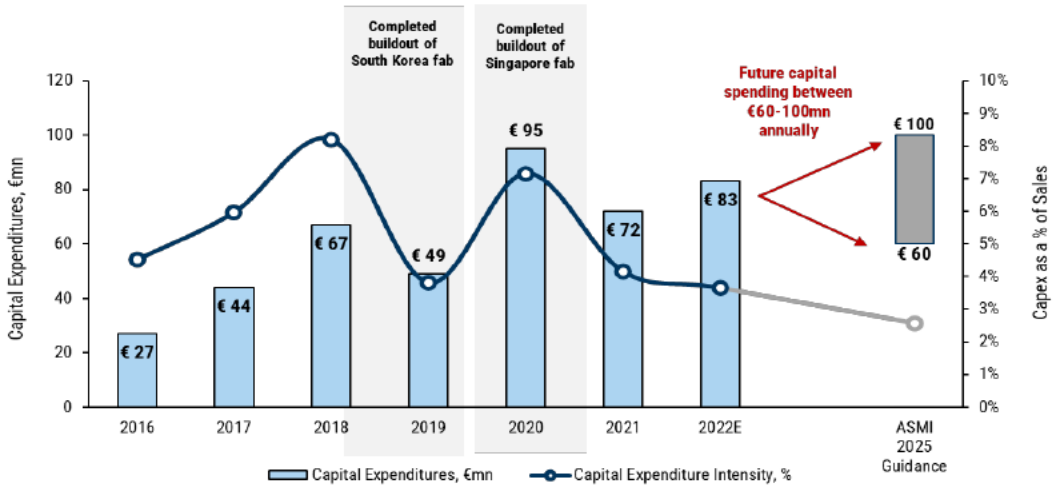
Exhibit 75: ASMI is benefitting from prior R&D investment in its ALD/Epitaxy product portfolio…
LHS: ASMI group R&D spend, €mn | RHS: ASMI group R&D as a % of sales



2025 figure assumes 10% R&D % of sales (mid-point of HSD to low-teens % guidance) and €3.1bn of sales (mid-point of sales guidance)

Source: Goldman Sachs Global Investment Research, Company data

Exhibit 76: …while recently completed facilities in South Korea/Singapore substantially expand capacity
LHS: ASMI group capex spend, €mn | RHS: ASMI group capex as a % of sales



Capital expenditure intensity % for 2025 is calculated using €3.1bn of sales and €80mn of capital expenditure at the mid-point of guidance

Source: Goldman Sachs Global Investment Research, Company data

We believe that ASMI has strong production capacity with new manufacturing plants expected to ramp up in coming years, albeit we expect the company to maintain elevated inventory levels as well as diversify its supply base to ensure a reduced effect from potential supply chain disruption.

Exhibit 77: We believe ASMI is in a strong capacity position, albeit we expect the company to maintain higher buffer stock going forward
Capacity and supply chain overview

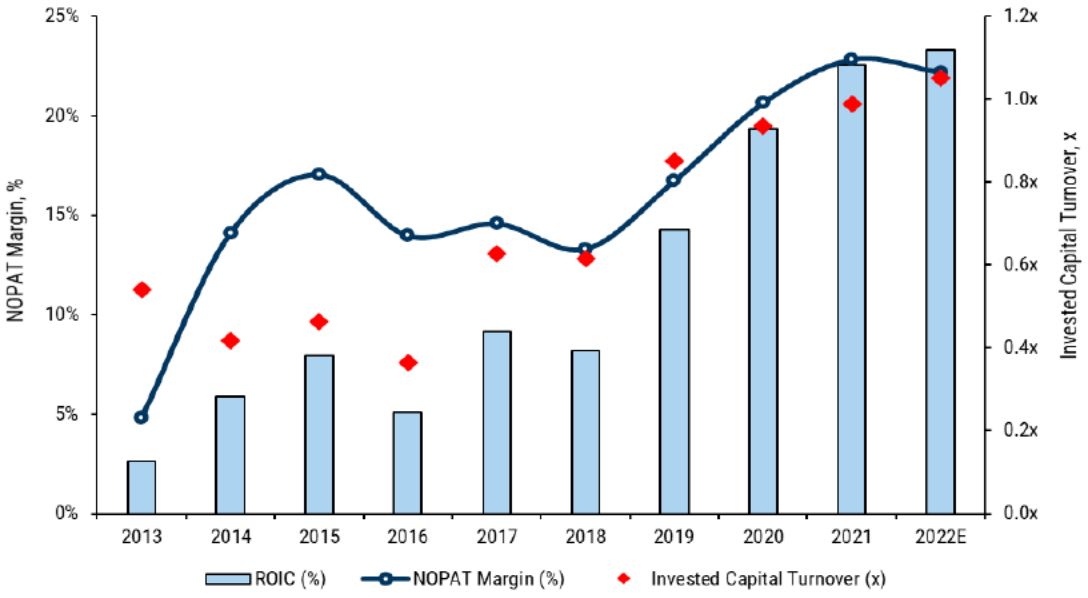
Overview of ASMI's Capacity and Supply Chain

Capacity	• We believe **ASMI is in a strong position capacity-wise**, since most of its assembly operations take place at its plant in **Singapore**, which was completed in 2020, and **ramped-up over 2021**
	  ◦ ASMI is currently utilizing the first floor, and the **second floor will be ready for production in early 2023**
	  ◦ With this expansion, ASMI will **more than triple its global manufacturing capacity** vs 2020

Supply Chain Constraints	• **Despite supply chain tightness** impacting the business in the first half of 2022, ASMI reported revenue of €560m in 2Q22, at **the higher end of its revenue guidance** • While **supply chain is improving slower than expected** in some areas, for other parts, lead times continue to be extended with **limited visibility for improvement** in the next few months
Addressing supply chain constraints	• ASMI has a **well diversified supplier base** and will strive to ensure at least 2 suppliers for each component. ◦ ASMI's strategy is to qualify and approve **more alternative suppliers** • ASMI will likely maintain **higher levels of buffer inventory** for critical materials due to supply chain constraints.

Source: Company data, Goldman Sachs Global Investment Research

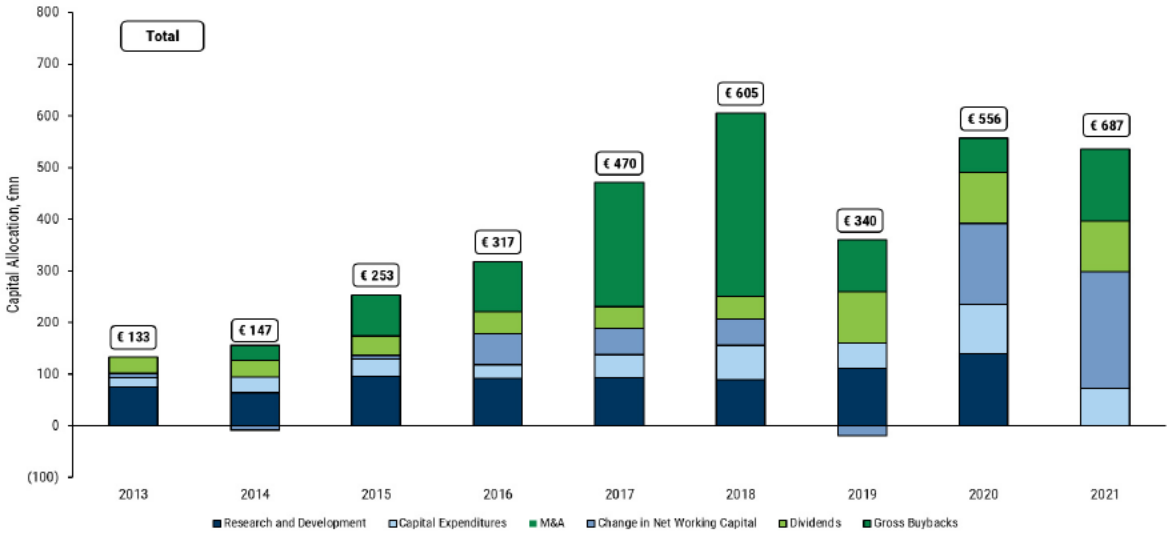
Exhibit 78: ASMI's ROIC has risen by by nearly 10x in the last 8 years, driven by higher margins and more efficient fab utilisation, in our view
LHS: ROIC, NOPAT margin (%) | RHS: Invested capital turnover (x)



Source: Goldman Sachs Global Investment Research, Company data

ASMI is focused on creating value for shareholders and has returned close to €1.4bn through buybacks and dividends since 2013.

Exhibit 79: Since 2013, ASMI has deployed c.€760mn in R&D, while returning just under €1.4bn to shareholders through buybacks and dividends
ASMI capital allocation



Source: Goldman Sachs Global Investment Research, Company data

Exhibit 80: We sense-check valuation and note that ASMI trades at a material discount to ASML because of the latter's monopoly status in the EUV business

ASML vs ASMI Comparison Metrics		
Category	ASML	ASMI
1 Market Segment	Lithography- EUV, DUV, High-NA	Deposition- ALD, Epitaxy
2 Revenue Growth *(FY21 – FY25E)*	14% CAGR (FY21 Rev: €18,611mn)	19% CAGR (FY21 Rev: €1,729mn)
3 Gross Margin *(2025E)*	56%	49%
4 Net R&D (% sales) *(2025E)*	12%	10%
5 Operating Margin *(2025E)*	40%	30%
6 EPS recurring *(2025E)*	€27.8	€19.0
7 10 Year Average ROIC % *(2012 - 2022E)*	34.5%	11.5%
8 PE Trading Multiple *(2023 GSe)*	20x	18x
10 EV/EBITDA Trading Multiple *(2023 GSe)*	16x	12x
11 PE Multiple *(12M Fwd cons.)*	24x	20x
12 EV/EBITDA Multiple *(12M Fwd cons)*	19x	14x

Source: Goldman Sachs Global Investment Research, Eikon Datastream

All share prices in the report as of the close of September 30, 2022, unless otherwise stated.

Disclosure Appendix

Reg AC

We, Alexander Duval and James Saunders, hereby certify that all of the views expressed in this report accurately reflect our personal views about the subject company or companies and its or their securities. We also certify that no part of our compensation was, is or will be, directly or indirectly, related to the specific recommendations or views expressed in this report.

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Growth is based on a stock's forward-looking sales growth, EBITDA growth and EPS growth (for financial stocks, only EPS and sales growth), with a higher percentile indicating a higher growth company. **Financial Returns** is based on a stock's forward-looking ROE, ROCE and CROCI (for financial stocks, only ROE), with a higher percentile indicating a company with higher financial returns. **Multiple** is based on a stock's forward-looking P/E, P/B, price/dividend (P/D), EV/EBITDA, EV/FCF and EV/Debt Adjusted Cash Flow (DACF) (for financial stocks, only P/E, P/B and P/D), with a higher percentile indicating a stock trading at a higher multiple. The **Integrated** percentile is calculated as the average of the Growth percentile, Financial Returns percentile and (100% - Multiple percentile).

Financial Returns and Multiple use the Goldman Sachs analyst forecasts at the fiscal year-end at least three quarters in the future. Growth uses inputs for the fiscal year at least seven quarters in the future compared with the year at least three quarters in the future (on a per-share basis for all metrics).

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Across our global coverage, we examine stocks using an M&A framework, considering both qualitative factors and quantitative factors (which may vary across sectors and regions) to incorporate the potential that certain companies could be acquired. We then assign a M&A rank as a means of scoring companies under our rated coverage from 1 to 3, with 1 representing high (30%-50%) probability of the company becoming an acquisition target, 2 representing medium (15%-30%) probability and 3 representing low (0%-15%) probability. For companies ranked 1 or 2, in line with our standard departmental guidelines we incorporate an M&A component into our target price. M&A rank of 3 is considered immaterial and therefore does not factor into our price target, and may or may not be discussed in research.

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