Automotive Industry
Semiconductor Outlook
Early signs suggest that the semiconductor supply will remain tight in the coming years

The automotive semiconductor market is expected to grow by more than 9% annually through 2030.

- The adoption of electric vehicles (EVs) and advanced driver-assistance systems (ADAS) will substantially increase the semiconductor content in vehicles, even as production volume remains steady.
- Battery electric vehicles (BEVs), which are expected to have the highest market share among EVs by 2026, have twice the semiconductor content of internal combustion engine (ICE) vehicles, owing to the need for discrete-power and analog chips.
- ADAS Level 2+ is expected to gain the largest market share among assistance systems. Each additional level of sophistication exponentially increases the need for memory and logic computing.

As a result, some semiconductor supply challenges are expected to persist through 2026.

- Shortages of analog chips and MEMS may persist given limited planned-capacity investments.
- Discrete-power chips may experience additional demand pressure with the adoption of 800-volt vehicles; there may be insufficient wide-bandgap manufacturing capacity to meet demand.
- Approximately 50% of future fabrication capacity is planned in mainland China, which will increase risk if the planned capacity does not come online or is inaccessible to Western OEMs and Tier 1 suppliers.
- Automotive demand growth will be highest for logic chips made on 20nm to 45nm nodes in order to meet the increasing computing needs of centralized electrical/electronic architectures; we expect this to ease demand pressure on mature node sizes larger than 55nm.

Source: BCG analysis.

Note: ADC = analog-to-digital converter; E/E = electrical/electronic; IGBT = insulated gate bipolar transistor; MEMS = microelectromechanical systems; MOSFET = metal oxide semiconductor field effect transistor; nm = nanometer; OEM = original equipment manufacturer.
Pandemic-induced manufacturing and logistics challenges are easing, but supply issues will persist

SEMICONDUCTOR DEMAND AND SUPPLY, INDEXED TO THE QUARTERLY AVERAGE OF 2018

Sources: BCG IC Model Forecast; BCG analysis.
Note: Semiconductors are purchased one quarter before the actual end-market sales year. Demand forecasts are determined by expected demand of representative industries. Supply forecasts are determined by foundry capacity. Semiconductor memory devices not included in this analysis.
The auto industry currently occupies a small share of the semiconductor market, but it’s growing rapidly

**GLOBAL SEMICONDUCTOR DEMAND BY SEGMENT (%)**

<table>
<thead>
<tr>
<th>Segment</th>
<th>2021</th>
<th>2026</th>
<th>CAGR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto</td>
<td>8</td>
<td>11</td>
<td>11%</td>
</tr>
<tr>
<td>Consumer electronics</td>
<td>23</td>
<td>27</td>
<td>4%</td>
</tr>
<tr>
<td>Data center</td>
<td>10</td>
<td>12</td>
<td>9%</td>
</tr>
<tr>
<td>Industrial</td>
<td>25</td>
<td>21</td>
<td>9%</td>
</tr>
<tr>
<td>Smart phones</td>
<td>14</td>
<td>10</td>
<td>2%</td>
</tr>
<tr>
<td>Other industries</td>
<td>9</td>
<td>9</td>
<td>7%</td>
</tr>
</tbody>
</table>

**2021–26 CAGR**

<table>
<thead>
<tr>
<th>Segment</th>
<th>CAGR</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>5%</td>
<td>Share expected to grow based on strong demand to support EVs and ADAS</td>
</tr>
<tr>
<td>Auto</td>
<td>11%</td>
<td>Stable growth, near market average</td>
</tr>
<tr>
<td>Consumer electronics</td>
<td>4%</td>
<td>Adoption of cloud storage and computing will support continued growth</td>
</tr>
<tr>
<td>Data center</td>
<td>9%</td>
<td>Strong demand growth expected, to support adoption of connected solutions and smart machines</td>
</tr>
<tr>
<td>Industrial</td>
<td>9%</td>
<td>Growth will slow coming out of 5G super cycle</td>
</tr>
<tr>
<td>Smart phones</td>
<td>2%</td>
<td>Pandemic-driven refresh cycle will trend downward before reaching steady state</td>
</tr>
<tr>
<td>Others¹</td>
<td>7%</td>
<td></td>
</tr>
</tbody>
</table>

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Sources: Gartner; BCG analysis.
1Other industries include aerospace and defense and communications infrastructure.
Increasing semiconductor content per vehicle will promote demand, even as total vehicle production remains steady.

**Forecast**

<table>
<thead>
<tr>
<th>Year</th>
<th>Light Vehicle Production (Millions)</th>
<th>Semiconductor Content Per Vehicle, Blended Average ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2021</td>
<td>77</td>
<td>+2.2%</td>
</tr>
<tr>
<td>2022</td>
<td>79</td>
<td></td>
</tr>
<tr>
<td>2023</td>
<td>83</td>
<td></td>
</tr>
<tr>
<td>2024</td>
<td>85</td>
<td></td>
</tr>
<tr>
<td>2025</td>
<td>88</td>
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</tr>
<tr>
<td>2026</td>
<td>89</td>
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</tr>
<tr>
<td>2027</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>2028</td>
<td>92</td>
<td></td>
</tr>
<tr>
<td>2029</td>
<td>93</td>
<td></td>
</tr>
<tr>
<td>2030</td>
<td>94</td>
<td></td>
</tr>
</tbody>
</table>

Sources: Gartner; Strategy Analytics; BCG IC model forecast; BCG analysis.
BEVs are expected to have the largest share of the market and require the most semiconductor content.
On average, BEV powertrains require more discrete-power chips and analog content than internal combustion engines

**Discrete**
Inverter, DC/DC, and OBC require substantially higher content of discrete chips in BEV power electronics

**SEMICONDUCTOR CONTENT ($)**

<table>
<thead>
<tr>
<th></th>
<th>ICE</th>
<th>BEV</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOSFET</td>
<td>20</td>
<td>125</td>
<td>330</td>
</tr>
<tr>
<td>IGBT</td>
<td>30</td>
<td>180</td>
<td></td>
</tr>
<tr>
<td>OBC</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note:**
ADC = analog-to-digital converter; BMC = battery management controller; DC/DC = direct current to direct current; IGBT = insulated gate bipolar transistor; MOSFET = metal oxide semiconductor field effect transistor; OBC = onboard charger; PIC = power integrated circuit.

**Analog**
Analog-to-digital signal converters translate critical sensory outputs in BEVs, driving analog demand

**SEMICONDUCTOR CONTENT ($)**

<table>
<thead>
<tr>
<th></th>
<th>ICE</th>
<th>BEV</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADC</td>
<td>80</td>
<td>80</td>
<td>90</td>
</tr>
<tr>
<td>PIC</td>
<td>90</td>
<td>140</td>
<td>240</td>
</tr>
</tbody>
</table>

**Sources:**
Gartner; Strategy Analytics; Morgan Stanley; Wells Fargo; expert interviews; BCG analysis.

**Note:**
ADC = analog-to-digital converter; BMC = battery management controller; DC/DC = direct current to direct current; IGBT = insulated gate bipolar transistor; MOSFET = metal oxide semiconductor field effect transistor; OBC = onboard charger; PIC = power integrated circuit.
ADAS Level 2+ will see the highest penetration growth through 2030, increasing demand for logic and memory.

**ADAS SHARE OF LIGHT VEHICLE PRODUCTION (%)**

<table>
<thead>
<tr>
<th>Year</th>
<th>None</th>
<th>Level 0/1</th>
<th>Level 2</th>
<th>Level 2+</th>
<th>Level 3</th>
<th>Level 4/S</th>
</tr>
</thead>
<tbody>
<tr>
<td>'21</td>
<td>21</td>
<td>3</td>
<td>5</td>
<td>7</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>'22</td>
<td>35</td>
<td>14</td>
<td>16</td>
<td>32</td>
<td>30</td>
<td>28</td>
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<tr>
<td>'23</td>
<td>41</td>
<td>20</td>
<td>18</td>
<td>29</td>
<td>26</td>
<td>24</td>
</tr>
<tr>
<td>'24</td>
<td>36</td>
<td>25</td>
<td>24</td>
<td>32</td>
<td>30</td>
<td>82</td>
</tr>
<tr>
<td>'25</td>
<td>30</td>
<td>20</td>
<td>21</td>
<td>34</td>
<td>32</td>
<td>22</td>
</tr>
<tr>
<td>'26</td>
<td>25</td>
<td>25</td>
<td>22</td>
<td>34</td>
<td>33</td>
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<tr>
<td>'27</td>
<td>20</td>
<td>20</td>
<td>23</td>
<td>33</td>
<td>33</td>
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<td>'28</td>
<td>18</td>
<td>18</td>
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<td>'29</td>
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<td>16</td>
<td>21</td>
<td>32</td>
<td>32</td>
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<tr>
<td>'30</td>
<td>14</td>
<td>14</td>
<td>16</td>
<td>32</td>
<td>32</td>
<td>32</td>
</tr>
</tbody>
</table>

**ADAS LOGIC CHIP CONTENT ($)**

- Level 0/1: 70
- Level 2: 240
- Level 2+: 380
- Level 3: 950
- Level 4/S: 3,170

**ADAS SEMICONDUCTOR CONTENT ($)**

- Highest growth: 3,170
- L0/1: 80
- L2: 290
- L2+: 730
- L3: 1,360
- L4/S: 3,850

Sources: Gartner; Strategy Analytics; BCG analysis.
Analog and MEMS will be the key semiconductor challenges through 2026

Sources: BCG IC model forecast; Gartner; Strategy Analytics; BCG analysis.
MEMS = microelectromechanical systems; Opto = optoelectronic.

1Expected 2026 supply divided by demand, indexed to 2018. Inflation adjusted.
2CAGR 2018 – 2026, inflation adjusted.
32021 automotive demand.

Potential risks for discrete-power and 20nm-45nm chips if expected supply capacity does not materialize

Key challenge for Automotive

Potential surplus

Scale=
$2.5 billion in demand

Logic
Other

Supply-demand ratio

Automotive demand growth, semiconductors

>90nm
80/90nm
55/65nm
<20nm
40/45nm
20/22nm
28/32nm
Discrete
Memory
Opto
Analog
MEMS/sensors

Need to manage closely

Sources: BCG IC model forecast; Gartner; Strategy Analytics; BCG analysis.
MEMS = microelectromechanical systems; Opto = optoelectronic.
1Expected 2026 supply divided by demand, indexed to 2018. Inflation adjusted.
2CAGR 2018 – 2026, inflation adjusted.
32021 automotive demand.
Automotives’ transition to more advanced logic nodes should ease demand pressure on mature sizes larger than 55 nanometers

Global semiconductor supply\(^1\) vs. demand\(^2\) forecasts, 2018–26
INDEXED TO 2018

<table>
<thead>
<tr>
<th>Node size (nm)</th>
<th>90+</th>
<th>80/90</th>
<th>55/65</th>
<th>40/45</th>
<th>28/32</th>
<th>20/22</th>
<th>&lt;20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mainland China’s share of new capacity(^3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indexed to 2018 = 100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potential surplus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potential surplus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potential surplus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Potential surplus is calculated as wafer manufacturing capacity (8-inch equivalent). Industry demand is modeled in inflation-adjusted US dollars. New capacity from 2018-2026.

Sources: SEMI; Gartner; Strategy Analytics; expert interviews; BCG analysis.

Note: S = supply; D = demand.
For nonlogic chips, automotive growth will place stress on analog and MEMS

Global semiconductor supply\(^1\) vs demand\(^2\) forecasts, 2018–26
INDEXED TO 2018

<table>
<thead>
<tr>
<th>Chip type</th>
<th>Analog</th>
<th>Discrete</th>
<th>Memory</th>
<th>MEMS</th>
<th>Opto</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential gap</td>
<td>Return to 2018 status quo</td>
<td>Potential surplus</td>
<td>Potential gap</td>
<td>Potential surplus</td>
<td></td>
</tr>
<tr>
<td>Mainland China’s share of new capacity(^3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indexed to 2018 = 100</td>
<td>131</td>
<td>169</td>
<td>143</td>
<td>160</td>
<td>140</td>
</tr>
<tr>
<td>S</td>
<td>D</td>
<td>S</td>
<td>D</td>
<td>S</td>
<td>D</td>
</tr>
</tbody>
</table>

Discrete chips may experience additional demand pressure with the adoption of 800-volt vehicles, but there may be insufficient wide-bandgap manufacturing capacity to meet demand.

Sources: SEMI; Gartner; Strategy Analytics; expert interviews; BCG analysis.
Note: S = supply; D = demand; MEMS = microelectromechanical systems; nm = nanometer; Opto = optoelectronic.
\(^1\)Semiconductor supply modeled as wafer manufacturing capacity (8-inch equivalent).
\(^2\)Industry demand modeled in inflation-adjusted US dollars.
\(^3\)New capacity from 2018-2026.
Uncertain access to mainland China’s fabrication capacity may increase risk in the automotive supply chain

Sources: SEMI; Bloomberg; expert interviews; BCG analysis.

Note: DUV = deep ultraviolet; EUV = extreme ultraviolet; OEM = original equipment manufacturer.

Approximately 50% of semiconductor capacity growth comes from mainland China

SEMICONDUCTOR CAPACITY, 2018–2023, (MILLIONS OF 8-INCH EQUIVALENTS)

Geopolitical risks that could create challenges for supply strategies

01 Planned capacity in mainland China does not come online
The US government is pushing ASML to stop sales of DUV lithography tools to mainland China (in addition to the existing EUV ban), inhibiting China’s ability to produce older nodes

02 Western OEMs and Tier 1 suppliers cannot access Chinese capacity
Recent and increasing trade tensions and tariffs create supply chain risk, potentially placing Western buyers at risk relative to local competitors

Increased demand may strain fabrication capacity outside of China as Western OEMs and Tier 1 suppliers try to mitigate potential geopolitical risks
Outside of mainland China, underinvestment in mature capacity persists owing to a cost penalty for new fabricators and older chips.

New fabrication plants see significantly higher wafer costs owing to high impact of depreciation.

Sources: IBS; BCG analysis.

Note: Deprecation expense is calculated based on a five-year period.

28nm is the current sweet spot for cost per density, significantly better than older nodes.

INDEXED COST PER 100 MILLION GATES
Automotive OEMs are implementing new semiconductor engagement models

### Engagement models

#### Direct agreements
- **BMW**
  - Inova Semiconductors
  - Global Foundries
- **GM**
  - Wolfspeed
- **Renault**
  - ST Microelectronics

#### Focus locally
- **Toyota**
  - Denso
- **Ford**
  - Global Foundries
- **7 suppliers**

#### Planning ahead
- **BMW/Mercedes**
  - Qualcomm/NVIDIA
- **VW**
  - ST Microelectronics
  - TSMC
- **Stellantis**
  - Foxconn
- **BYD**
  - BYD Semicon.

#### Own it yourself
- **Tesla**
  - TSMC/Samsung Foundry
- **Hyundai**
  - Hyundai Mobis

| Source(s) | Press releases; public information (such as interviews) from OEMs, integrated device manufacturers, and foundries; BCG analysis. |
| Note(s) | IC = integrated circuit; LED = light emitting diode; MCU = microcontroller; SiC = silicon carbide; SoC = system on a chip. |
Key actions to take now to ensure success going forward

**Stay focused on building resilient supply chains**
- Continue to use crisis-response centers to create transparency and promote cross-functional collaboration
- Invest in collaborative three-way relationships with Tier 1 suppliers and IDMs to secure access to current-generation semiconductors
- Optimize your inventory plan and properly account for potential geopolitical risks

**Align semiconductor strategy with product strategy**
- Evaluate platform-architecture designs and procurement with a focus on reducing semiconductor supply risks
- Cooperate to forge consortium, share chip design efforts, drive standards across Tier 1 suppliers and IDMs, and enable semiconductor capacity sharing
- Codevelop differentiating ICs with IDMs and foundries for the next generation of MCU and MPUs

**Shape your future**
- Establish your place in the value chain—from software to semiconductors—and plan build, buy, or partner strategies
- Develop clear, robust fact bases and analyses to help inform policymakers of the full impact of their decisions

Source: BCG analysis.
Note: IC = integrated circuits; IDM = integrated device manufacturer; MCU = microcontrollers; MPU = microprocessors.
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