Sustainable Products

**Strategies**

**Product Life Cycle Management**
Based on the Company's comprehensive strategy on product life cycle management, TSMC assesses the environmental and social impacts its products will bring at every stage of the life cycle in order to provide customers with products that have low environmental, carbon, and water footprints.

**Hazardous Substance Management**
Continue to execute projects on the substitution of hazardous raw materials used in the manufacturing process.

**Long-term Goals**
- Complete life cycle assessments on all factory-wide products.  
  ○ Target Year: 2019
- 100% compliance with legal regulations and customer standards on hazardous-substance-free products  
  ○ Target Year: In progress
- Reduce the use of N-methylpyrrolidone (NMP) by 95%, compared to 2016  
  ○ Target Year: 2020

**2018 Achievements**
- 100% compliance with legal regulations and customer standards on hazardous-substance-free products  
  ○ Target: 100%
- 86% completion of substituting all PFOA-related substances  
  ○ Target: 100%
- 48% reduction in the use of NMP  
  ○ Target: 70%

**2019 Targets**
- Complete life cycle assessments on all factory-wide products
- 100% compliance with legal regulations and customer standards on hazardous-substance-free products  
  ○ Target: 100%
- 100% completion of substituting all PFOA-related substances.
- 70% reduction in the use of NMP.

**Note** Since the substitute chemicals have been found to affect the yield of certain products, further adjustments and testing are needed.
Striving for a Lower Environmental Footprint by Creating Sustainable Products

At TSMC, product life cycle is taken into serious consideration in order to lower a product’s environmental footprint, thereby reducing its environmental and social impacts, as well as its energy consumption. Close attention is also given to the assessment and selection of lower hazard substances such that products comply with hazardous-substance-free standards. A drive towards ever-advancing manufacturing processes means that TSMC can assist customers in creating even higher energy-efficient designs for sustainable products that are both innovative and environmentally friendly.

Product Life Cycle Management

TSMC carefully considers environmental impacts at every stage of the product life cycle. This includes collaboration with customers on product development, the production and transportation of raw materials, and product manufacturing, testing, and packaging. The Company also strives to set high standards throughout the manufacturing process in the areas of hazardous substance management, pollution prevention, energy-efficiency, and natural resource consumption. In order to lower the environmental, carbon, and water footprints of semiconductor products throughout their life cycle, TSMC requires and assists suppliers to take proper steps towards environmental protection.
In 2018, TSMC initiated a project to update product life cycle assessments, carbon footprint and water footprint across all company fabs. Assessments and third-party verification were completed, and the Company received ISO14040, ISO14067 and ISO14046 certifications. Examinations of the product life cycle, carbon footprint, and water footprint of wafer products have shown that more than 70% of major environmental impact comes from wafer fabrication. In the upstream supply chain, environmental impacts mainly stem from raw silicon wafers, chemicals, and gases. In efforts to reduce the environmental footprint of its products, TSMC is continuing to make progress in company-wide reductions of greenhouse gas emissions, energy and water conservation, waste minimization and reusability cycles, and pollution prevention. The Company also actively requires and assists its upstream and downstream supply chain partners to invest in similar initiatives.

**Completed Wafer Life Cycle Assessment**
(12-inch wafer as an example)

<table>
<thead>
<tr>
<th>Environmental Impact Category</th>
<th>Raw Material</th>
<th>Manufacturing</th>
<th>Transportation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate change</td>
<td>20.04%</td>
<td>79.30%</td>
<td>0.66%</td>
</tr>
<tr>
<td>Ozone depletion</td>
<td>0.00%</td>
<td>0.00%</td>
<td>100%</td>
</tr>
<tr>
<td>Evaluation of Human toxicity, cancer effects</td>
<td>0.00%</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>Particulate matter</td>
<td>25.68%</td>
<td>73.61%</td>
<td>0.70%</td>
</tr>
<tr>
<td>Ionizing radiation HH</td>
<td>20.61%</td>
<td>79.11%</td>
<td>0.28%</td>
</tr>
<tr>
<td>Ionizing radiation E (interim)</td>
<td>45.00%</td>
<td>75.00%</td>
<td></td>
</tr>
<tr>
<td>Photochemical ozone formation</td>
<td>26.12%</td>
<td>71.43%</td>
<td>2.45%</td>
</tr>
</tbody>
</table>

**Acidification**
Unit: mol H+ eq

<table>
<thead>
<tr>
<th>Raw Material</th>
<th>Manufacturing</th>
<th>Transportation</th>
</tr>
</thead>
<tbody>
<tr>
<td>25.02%</td>
<td>71.22%</td>
<td>0.95%</td>
</tr>
</tbody>
</table>

**Terrestrial eutrophication**
Unit: mol N eq

<table>
<thead>
<tr>
<th>Raw Material</th>
<th>Manufacturing</th>
<th>Transportation</th>
</tr>
</thead>
<tbody>
<tr>
<td>26.14%</td>
<td>71.32%</td>
<td>2.54%</td>
</tr>
</tbody>
</table>

**Freshwater eutrophication**
Unit: kg P eq

<table>
<thead>
<tr>
<th>Raw Material</th>
<th>Manufacturing</th>
<th>Transportation</th>
</tr>
</thead>
<tbody>
<tr>
<td>21.68%</td>
<td>78.22%</td>
<td>0.10%</td>
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</table>

**Marine eutrophication**
Unit: kg N eq

<table>
<thead>
<tr>
<th>Raw Material</th>
<th>Manufacturing</th>
<th>Transportation</th>
</tr>
</thead>
<tbody>
<tr>
<td>26.23%</td>
<td>71.72%</td>
<td>2.05%</td>
</tr>
</tbody>
</table>

**Freshwater ecotoxicity**
Unit: CTUe

<table>
<thead>
<tr>
<th>Raw Material</th>
<th>Manufacturing</th>
<th>Transportation</th>
</tr>
</thead>
<tbody>
<tr>
<td>29.14%</td>
<td>69.75%</td>
<td>1.11%</td>
</tr>
</tbody>
</table>

**Land use**
Unit: kg C deficit

<table>
<thead>
<tr>
<th>Raw Material</th>
<th>Manufacturing</th>
<th>Transportation</th>
</tr>
</thead>
<tbody>
<tr>
<td>29.32%</td>
<td>65.74%</td>
<td>4.94%</td>
</tr>
</tbody>
</table>

**Water resource depletion**
Unit: m³ water eq

<table>
<thead>
<tr>
<th>Raw Material</th>
<th>Manufacturing</th>
<th>Transportation</th>
</tr>
</thead>
<tbody>
<tr>
<td>81.84%</td>
<td>18.13%</td>
<td>0.03%</td>
</tr>
</tbody>
</table>

**Mineral, fossil & ren resource depletion**
Unit: kg Sb eq

<table>
<thead>
<tr>
<th>Raw Material</th>
<th>Manufacturing</th>
<th>Transportation</th>
</tr>
</thead>
<tbody>
<tr>
<td>80.68%</td>
<td>15.91%</td>
<td>3.41%</td>
</tr>
</tbody>
</table>

**Carbon Footprint of Wafer Products**
(12-inch wafers)

- Chemicals and gases: 14.50%
- Wafers: 10.21%
- Bulk gas: 6.70%
- Waste materials: 4.79%
- Water pollution: 0.21%
- Packaging materials: 0.02%
- Raw material extraction and production: 27%
- In-fab direct water use: 42%
- In-fab energy consumption: 31%
Hazardous Substance Management

TSMC gives serious consideration to social impacts throughout the product life cycle. The Company practices quality occupational health and safety management to create a safe and healthy work environment, and also adheres to standards set by the Responsible Business Alliance’s (RBA) Code of Conduct when interacting with customers and suppliers in order to improve workplace health and safety performance in the supply chain. In the usage stage of semiconductor products, TSMC is driven to make everyday living more convenient and to advance capabilities in the areas of health, safety, and more.

TSMC has established a management system for hazardous substances in products by promoting and receiving QC 080000 Hazardous Substances Process Management (HSPM) certification. Throughout the manufacturing process, design, and development stages, TSMC follows the principles of green design, avoids the use of raw materials containing hazardous substances in manufacturing, and ensures that all products comply with domestic and international regulations, as well as customer standards on the restriction of products containing hazardous substances. In the stage of raw materials procurement, TSMC has established a green procurement process. This process involves strict reviewing and management over any new raw materials planned to use in the phases of research and development, production, and engineering change. Source inspection from beginning means that all raw materials are in compliance with TSMC’s specifications for restricted hazardous substances.

Product Hazardous Substance Management Phases

Hazardous Substance Management is Compliant with or Surpasses International Regulations

<table>
<thead>
<tr>
<th>International Regulations / Customer Requirements</th>
<th>Description of Legal Compliance</th>
</tr>
</thead>
</table>
| European Union Restriction of Hazardous Substance (EU RoHS) | • TSMC provides lead-free bumps to customers. A few customers still need trace lead contained bump which is exempted by EU RoHS  
• Other EU RoHS restricted substances are not used in TSMC process |
| Product Halogen Free Requirements | • All TSMC products are compliant |
| Perfluorooctanesulfonic Acid (PFOS), Perfluorooctanoic Acid (PFOA) Restriction in Process | • TSMC has totally phased out using PFOS and PFOA, and all products also do not contain these two substances |
| EU Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) Annex XVII | • All TSMC products are compliant |
| EU REACH Substances of Very High Concern (SVHC) | • All TSMC products are compliant |
| EU Waste Electrical and Electronic Equipment (WEEE) Directive | • TSMC’s products are not final products and this law is not directly applicable |
It is possible that the use of certain raw materials containing hazardous substances will be restricted or banned in the future. In response, the Company has proactively taken measures to assess manufacturing and chemical substitutes, which are to be gradually implemented via designated multi-year projects.

TSMC has always upheld its stance towards avoiding or restricting the use substances that are carcinogenic, mutagenic, or toxic for production (CMR substances) in its management of substances used in the manufacturing process. When the use of such substances is unavoidable in the manufacturing, research, and development processes, a respective unit must draft a rigorous EHS protection plan. The plan then undergoes a stringent review process by the internal board to ensure EHS-related risks are as low as possible. Usage permission is given when the plan has been approved by VP-level executives.

In recent years, perfluoroalkyl substances (PFASs) have received worldwide attention due to its potentially adverse effects on humans and the environment. An increasing number of countries have responded by proposing relevant laws and regulations. Prior to 2016, TSMC had already initiated projects to substitute PFOA precursors, derivatives, and other related substances. However, evaluations of new substitutes have often found that these substances may negatively affect product yield during testing. This consequently requires adjustments to processing parameters and repeated testing until the issues are resolved. As of the end of 2018, 86% of PFOA related substances substitutes have been implemented, with the use of all PFOA-related substances expected to be completely phased out in 2019. In regards to short-chain PFASs, TSMC continues to monitor the impact of these substances on humans and environment, as well as any laws and regulations instituted by other countries. Any countermeasures will be taken as early as possible when needed. TSMC also puts a lot of efforts to reduce its use of NMP, a substance commonly used in the industry that has since been recognized to be toxic for reproduction. As of 2018, company-wide use of NMP has dropped by 48% compared to 2016.

### PFASs Laws and Regulations & TSMC’s Responsive Actions

#### International Laws and Regulations

- **PFOS**
  - Stockholm Convention on Persistent Organic Pollutants
  - Usage restricted in various countries starting 2010

- **PFOA**
  - Listed by the European Chemicals Agency (ECHA) as a substance of very high concern (SVHC)
  - Starting 2013, any products imported into EU that are found to contain PFOA must be disclosed

- **PFOA-related substances**
  - Listed by the ECHA as a SVHC
  - Starting 2015, any products imported into EU that are found to contain PFOA-related substances must be disclosed

- **Short-chain PFASs**
  - The EU and the Environmental Protection Agency (EPA) of the United States have begun assessing whether the substances pose any harm

#### TSMC’s Responsive Action

- **PFOS**
  - 2010 - Completed implementation of substitutes

- **PFOA**
  - 2015 - Completed implementation of substitutes ahead of legal regulations

- **PFOA-related substances**
  - Starting 2017, monitor assessments conducted by the EU and EPA
  - Conduct research plans for substitutes

- **Short-chain PFAS**
  - 2019 - Expected completion of substitute implementation, ahead of legal regulations

Substitution complete, Substitution in progress, Substitution under study
Help Customers Create Global Energy-saving Sustainable Products

The constant improvement of semiconductor manufacturing technology continues to boost the advancement of all products. Semiconductor-containing products are becoming increasingly energy-efficient, and their various smart applications in areas including smart construction, smart manufacturing, and smart grids are allowing users to save energy while improving work efficiency.

From 2015 up through 2018, TSMC has continually collaborated with the Industry, Science and Technology International Strategy Center (ISTI) of the Industrial Technology Research Institute (ITRI) to research avenues where the advancement and application of semiconductor products and techniques can improve the energy-efficiency of computers, communication, data centers, power plants, and ultimately the whole of Taiwan.

Studies by ISTI have shown that for every 1.0% increase in cumulative investments towards research and development, there is a 0.27—0.30% decrease in electric energy consumption. An analysis of the total amount of national research and development expenditures accounted for 33.3% - a 6.2% increase since 2016 - thus marking the Company as a key spender towards Taiwan’s domestic semiconductor R&D. The diffusion of benefits associated with TSMC’s R&D and products has been conducive to

Reduce use of NMP and Lower EHS Risks

Since 2018, TSMC has continuously reduced its use of the harmful substance, NMP. It has already completed key testing on the manufacturing process of substitutes and begun implementing these substances at each fab. Because NMP is a substance toxic for reproduction, TSMC ensures that its work environment assessment result is far below the limit stipulated in legal restrictions. The Company also follows best practices on protection to prevent human exposure to the chemicals. The use of NMP is avoided whenever possible during reviews of newly processed chemicals. TSMC will continue to carry out plans to reduce its use of NMP. It is expected that by 2020, NMP use will be reduced by 95%.

NMP Reduction Milestones

- **1993**: Pioneered to install an independent NMP waste liquid collection system.
- **2015**: Listed NMP and other CMR substances as controlled substances to avoid in the production of new materials.
- **2016**: Created and implemented a new liquid photoresist in the photoresist stripping and cleaning process.
- **2017**: Substituted NMP with ultrapure water combined with carbon dioxide, effectively reducing the use of NMP.

Case Study

**Simulation Model of Semiconductor Industry R&D and Industrial Electric Energy Consumption**

**ISTI Simulation Modeling Analysis**

- **Scenario 1**: If the semiconductor industry halts development of R&D and application over the past five years and is compared with Scenario 1 (where R&D and application are halted), then by 2025, it will potentially lead to industrial electric energy savings of 13% in Taiwan.
- **Scenario 2**: If the semiconductor industry develops regularly according to the cumulative rate of R&D and application over the past five years and is compared with Scenario 1, it will potentially lead to an additional 10% in Taiwan’s industrial electric energy savings.
- **Scenario 3**: If the semiconductor industry increases the development on the cumulative rate of R&D and application over the past five years and is compared with Scenario 2, by 2025, it will potentially lead to an additional 10% in Taiwan’s industrial electric energy savings.

Source: ISTI
both increasing the country's energy efficiency and decreasing its consumption of electric energy.

More Advanced and More Energy-efficient Electronic Products

New-generation IC manufacturing technologies make circuit line widths shrink, leading to a smaller IC chip and lower product power consumption. TSMC is consistently first among dedicated foundries to provide next-generation, leading-edge technologies. The Company also provides comprehensive specialty technologies and excellent frontend and backend integration capabilities. These help customers produce more advanced, energy-saving and environmentally friendly products to minimize the environmental impact of technology progress. With TSMC’s manufacturing technologies, customers can unleash their design innovations in a wide range of applications including computer, communications, consumer, industrial and other electronic products, significantly contributing to the progress in our modern society.

One remarkable example is that Broadcom achieved mass production of its industry-leading 12.8 Tbps Tomahawk® 3 Ethernet Switch Family in 2018, using TSMC’s industry-leading 16nm technology, enables massive scale-out cloud data centers to keep up with the exponential growth in data traffic in the 5G era. (Photo courtesy of Broadcom)

it significantly reduces cost per 100GbE port by 75% and power-per-100GbE port by 40% compared to existing solutions. It supports high-density and configurable interconnect, including 32x400GbE, 64x200GbE, and 128x100GbE, for massive scale-out cloud data centers. It is a key catalyst for next generation cloud networks enabling data center operators to upgrade and scale their network infrastructure in order to keep up with the exponential growth in data traffic due to booming of IoT devices, content streaming, and artificial intelligence applications in the 5G era.

Chip Die Size Cross-Technology Comparison

Die size is shrinking as line width shrinks

Source: TSMC

<table>
<thead>
<tr>
<th>Technology</th>
<th>Die Size (μm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>55 nm</td>
<td>1.0</td>
</tr>
<tr>
<td>40 nm</td>
<td>0.48</td>
</tr>
<tr>
<td>28 nm</td>
<td>0.25</td>
</tr>
<tr>
<td>16 / 12FFC</td>
<td>0.11</td>
</tr>
<tr>
<td>10 nm</td>
<td>0.063</td>
</tr>
<tr>
<td>7 nm</td>
<td>0.047</td>
</tr>
<tr>
<td>5 nm</td>
<td>0.035</td>
</tr>
</tbody>
</table>

Note: The logic chip / SRAM / IO (Input / Output) ratio, which affects die size and power consumption, was re-aligned.

Chip Total Power Consumption Cross-Technology Comparison

More power is saved as line width shrinks

Source: TSMC

<table>
<thead>
<tr>
<th>Technology</th>
<th>Total Power Consumption (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N55LP (1.2V)</td>
<td>1.0</td>
</tr>
<tr>
<td>N40LP (1.1V)</td>
<td>0.6</td>
</tr>
<tr>
<td>N28HPM (0.9V)</td>
<td>0.3</td>
</tr>
<tr>
<td>N16 / 12FFC (0.8V)</td>
<td>0.07</td>
</tr>
<tr>
<td>10 nm (0.75V)</td>
<td>0.056</td>
</tr>
<tr>
<td>7 nm (0.75V)</td>
<td>0.034</td>
</tr>
<tr>
<td>5 nm (0.75V)</td>
<td>0.022</td>
</tr>
</tbody>
</table>

Note: The logic chip / SRAM / IO (Input / Output) ratio, which affects die size and power consumption, was re-aligned.
Unleash Customers’ Chip Innovations that Enhance Mobility and Convenience

The rapid growth of smartphones and tablets in recent years reflects people’s strong demand for mobile devices and high expectation for a convenient life. TSMC is committed to unleashing customers’ mobile and wireless chip innovations and has already made significant contributions.

- New TSMC process technology helps chips achieve faster computing speeds in a smaller die area, leading to smaller form factors for electronic devices.
- TSMC SoC technology integrates more functions into one chip, reducing the total number of chips in electronic devices, resulting in a smaller system form factor.
- New TSMC process technology helps chips consume less energy. People can therefore use mobile devices for a longer period of time.
- TSMC helps unleash more convenient wireless connectivity such as 3G / 4G and WLAN / Bluetooth, meaning people can communicate more efficiently and “work anytime and anywhere,” significantly improving the mobility of modern society.

Unleash Customer’s Innovations to Improve Human Health and Safety

TSMC continues to enhance or develop innovative CIS (CMOS image sensor) and MEMS (micro electro mechanical systems) technologies, which are expanding from traditional sensing to machine sensing. By combining advantages of traditional sensing and machine sensing, new products using TSMC CIS and MEMS technologies can be made smaller and faster, while consuming less power, and bringing people a more convenient, healthy, and safe lifestyle.

In 2018, TSMC successfully delivered the world’s first CMOS-MEMS (micro-electromechanical systems) monolithic capacitive barometer, which features sensitivity to change in altitude as small as 5 cm and fits in a package of slightly less than 1 mm², for various system applications, including personal activity tracking and indoor navigation.

- Extend traditional sensing to machine sensing, such as NIR (near infrared), ultrasound, and micro-actuators, etc.
- Adopted for consumer electronics, smartphones and other electronic devices make our lives more convenient.
- Adopted for advanced medical treatments and preventative health care applications improve human health.
- Adopted for automotive electronics to improve car safety systems.