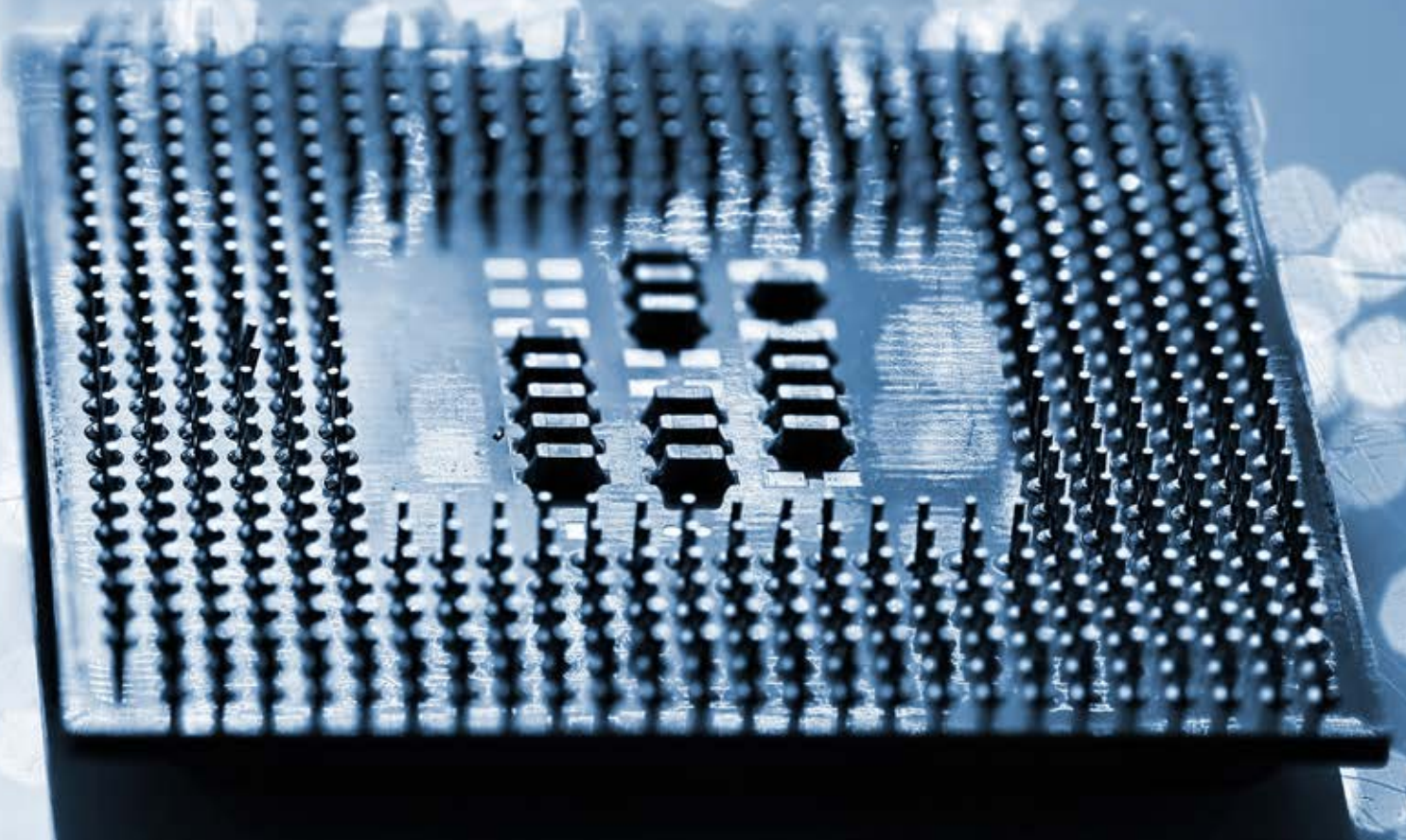


THE LINDE GROUP

Linde

Leading in electronic gases

Supplying the semiconductor, solar,
display, and LED markets



Your electronics partner.

We know that our customers face a lot of demands and challenges...to be innovative, to be on the cutting edge of technology, and to deliver quality products globally and on time...the same things we care about.





To help you be successful, we partner with you by making ongoing investments in processes, engineering, and on-site and localized solutions. We work closely with you to better understand, anticipate, and meet your evolving needs.

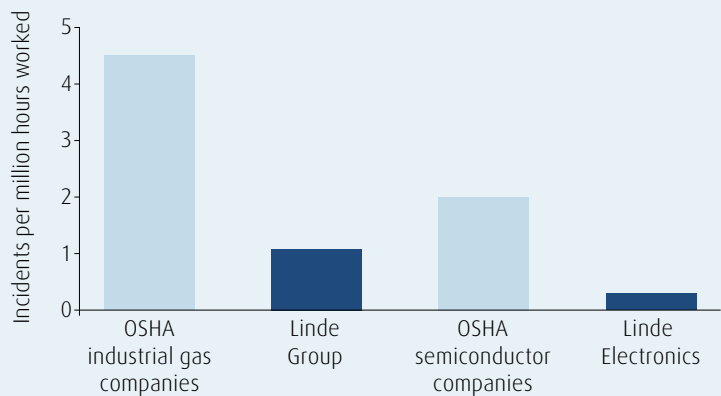
We offer a broad portfolio that includes environmentally sustainable solutions, rigorously controlled electronic specialty gases (ESGs), bulk and pipeline gases, equipment, and services.

Safety

At Linde, our aim is to avoid causing any harm to people or the environment. We continually strive to improve the quality and safety of our products and services. The health and safety of our employees and our customers and the protection of the environment are just as important to us.

- Safety-first culture
- Safety embedded into our processes
- Committed to achieving a zero-incident business

Lost Time Incident Rate

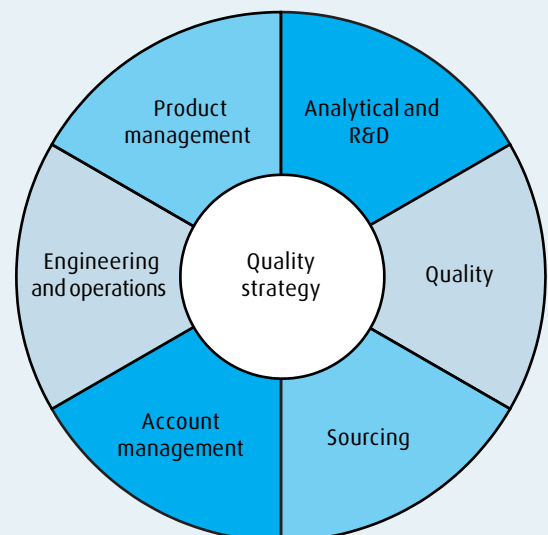


Quality

We provide a holistic, interlinked, and comprehensive quality system and cover the entire supply chain from raw material supply to the delivery of our final products at the point of use in our customers' fabs.

We provide the best quality products through:

- Rigorous measurement
- Gas purity, consistency, and reliability
- Business continuity planning
- Process and statistical quality control



Linde's network of bulk gas production plants ensures reliable supply of ultra-high purity in any required volume of nitrogen, oxygen, argon, hydrogen, helium, and carbon dioxide.



Commitment

We are committed to the electronics industry, our partners, and our people. We demonstrate our commitment through:

- Investment in bulk and pipeline infrastructure in cluster parks
- Collaboration with customers on on-site and local solutions
- Development of new applications to broaden our ESG portfolio
- Partnerships with raw material suppliers

Expertise

We offer a broad portfolio of products and services that add the highest value to our customers.

Our key capabilities are:

- On-site plants (design, manufacture, and operation)
- Bulk gases (continuous high-purity delivery)
- Special gases (synthesis, purification, blending, analysis, and packaging)
- On-site services (material delivery and management)
- Procurement and global supply chain management

Linde is the leader in making high-purity bulk CO₂ available for lithography and cleaning applications.



Linde's Generation-F® fluorine technology delivers cost-effective chamber cleaning solutions, which speed production and reduce environmental impact by replacing global warming gases.

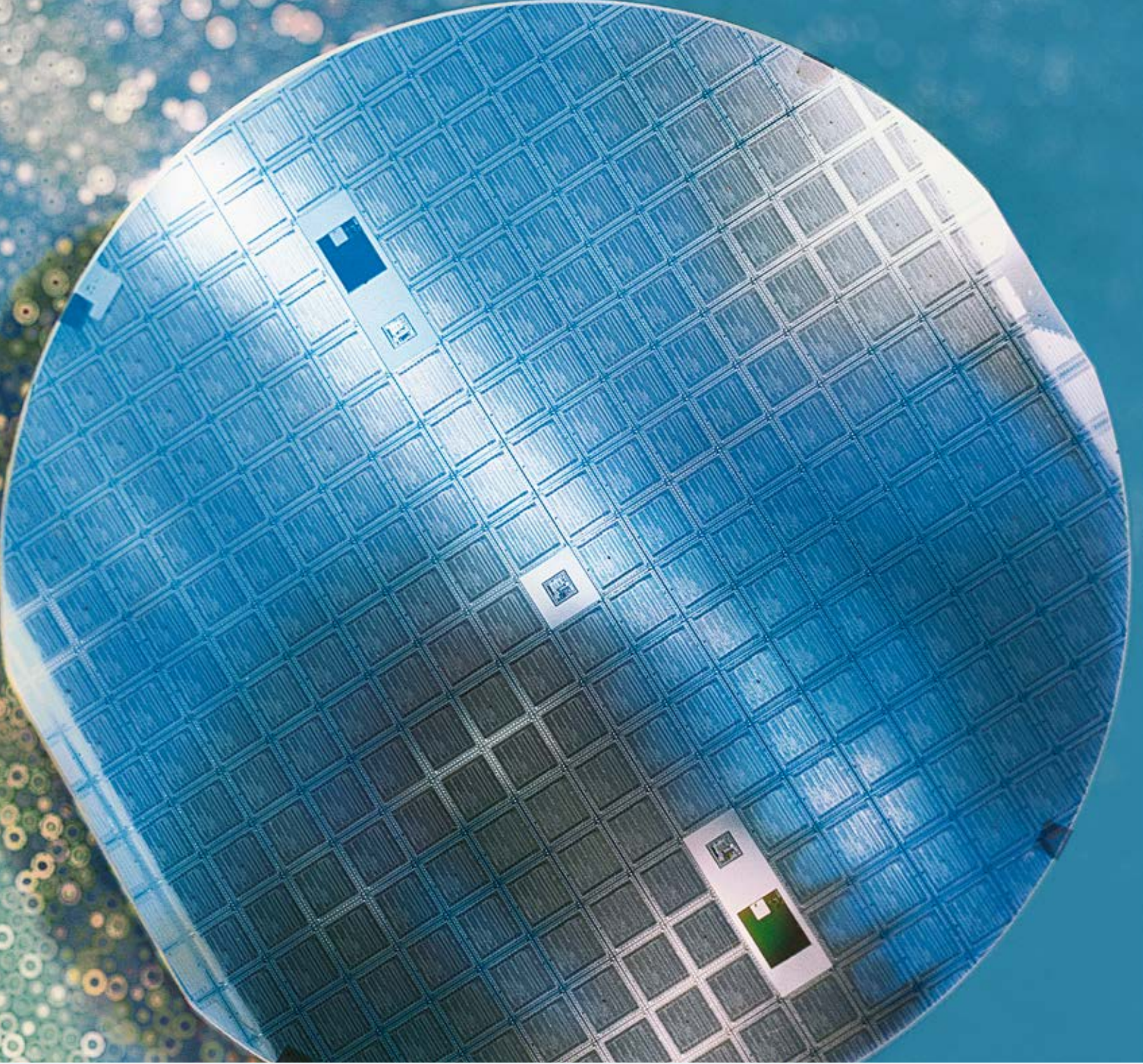


Environmental leadership

Electronics manufacturing plants are not always located in the optimum position for materials supplies, making it vital to think about how materials can be recovered, purified, and re-used on-site, saving shipping costs, reducing logistics risks, and decreasing carbon footprint.

We support sustainable manufacturing through:

- Energy-efficient SPECTRA® nitrogen plants
- Materials recycling and recovery
- Fluorine technology to reduce emissions
- On-site solutions to reduce carbon footprint



Semiconductor market

Leveraging our global footprint to supply ultra-pure gases, chemicals, and services to any wafer fab in the world.

The semiconductor industry is one of the most dynamic, sophisticated, and competitive markets worldwide. As it continues to grow, so too does the demand for ultra-pure gases and chemicals. Fab operators need a reliable and responsive partner with a global reach and the technical capability to safely ensure the highest quality, manage costs, reduce environmental impact, and innovate for the future.

Linde is the technology partner of choice for global semiconductor manufacturers. We offer a broad portfolio of electronic specialty gas and bulk solutions — backed by a global supply chain — to bring you high quality, rigorously measured, consistent, reliable, and more sustainable semiconductor manufacturing processes.

Electronic Specialty Gases

There are hundreds of electronic specialty gases used in the manufacture of semiconductors. These are some of the most common ESGs that Linde offers:

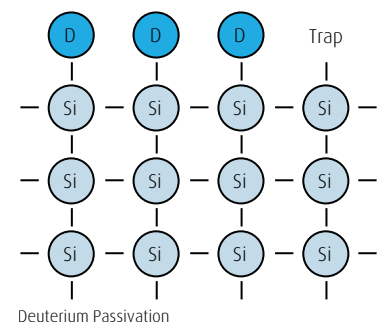
Nitrogen trifluoride (NF ₃)	Cleaning of process chambers and etching
Tungsten hexafluoride (WF ₆)	Low pressure or plasma-enhanced CVD (chemical vapor deposition) of tungsten, tungsten silicides, and tungsten nitrides
Hydrogen chloride (HCl)	Epitaxial and cleaning processes
Ammonia (NH ₃)	Chemical vapor deposition process
Disilane (Si ₂ H ₆)	Low-temperature silicon deposition for making high-quality ultra-thin epitaxial films in advanced technology nodes
Germane (GeH ₄)	Precursor used to form and deposit the SiGe (silicon-germanium) layer on silicon wafers
High-purity carbon dioxide (CO ₂)	Treatment of the immersion water supply for immersion lithography tools
Nitrous oxide (N ₂ O)	Chemical vapor and atomic layer deposition

Lithography gases

Linde is the recognized leader for the manufacture of DUV (deep ultraviolet) excimer gas mixtures. Our SPECTRA lithography gases have enabled semiconductor patterning for over 20 years. We combine a prime position in rare gases and halogens with proprietary expertise in blending, analysis, and cylinder treatment to ensure our customers' lithography equipment achieves the highest level of stability and up-time.

Isotopes

Our production and purification technology extends beyond the molecular level to achieve isotopically pure special gases for a number of leading-edge applications. ¹¹B_{F₃ and other ¹¹B compounds allow for devices designed to avoid the disabling effects from thermal neutron capture. Similarly, deuterium (D₂) and deuterium-substituted gases are used to make devices robust to hot electron damage. As Moore's Law drives device dimensions below 10nm, Linde's isotopically-enriched solutions help create successful designs at the smallest achievable scales.}

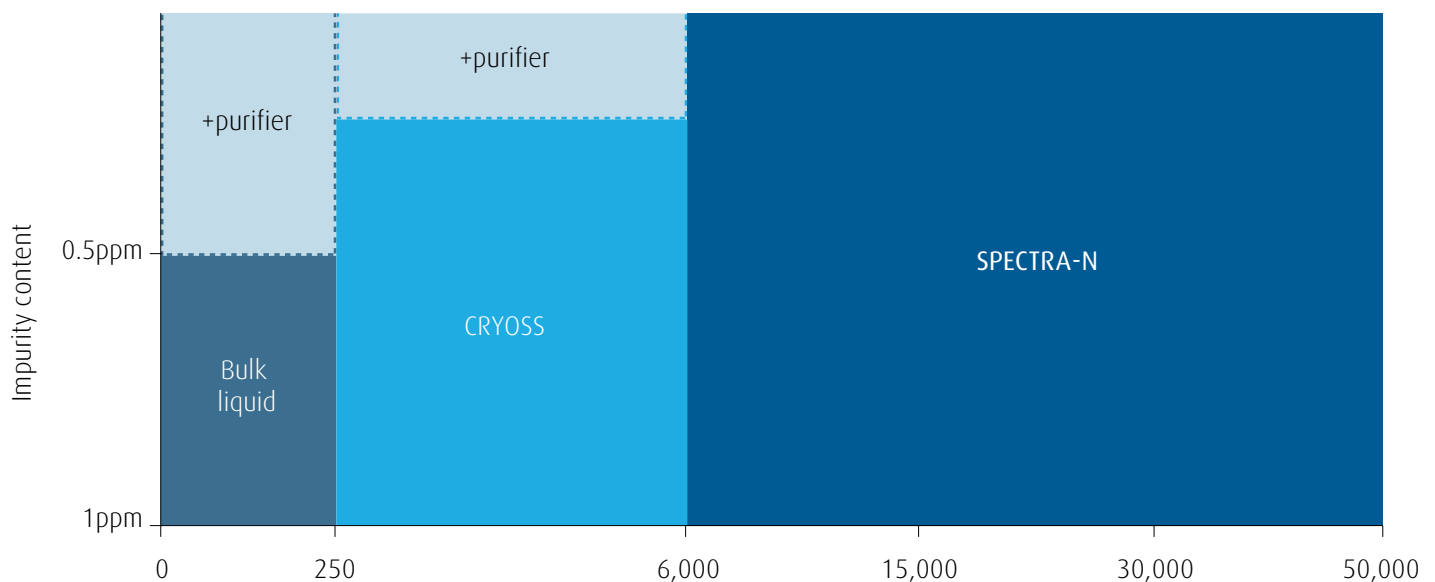


Electronic Bulk Gases

The major bulk gases used in the manufacture of semiconductors are nitrogen, hydrogen, argon, helium, oxygen, and carbon dioxide.

Nitrogen	N ₂ is by far the most used gas in semiconductor manufacturing. It is used for purging vacuum pumps, in abatement systems, and as a process gas. In large, advanced fabs, consumption of nitrogen can reach 50,000 cubic meters per hour, which makes the case for cost-effective, low-energy, on-site nitrogen generators.
Hydrogen	H ₂ is increasing in usage due to larger fabs and higher process intensity. It is used during epitaxial deposition of silicon and silicon germanium and for surface preparation. With the move to EUV (extreme ultra violet), hydrogen demand will continue to grow. Linde is ready and can deliver hydrogen as compressed gas or in liquid form (only in US and Europe), or on-site through steam reforming or electrolysis.
Argon	Ar is used ubiquitously in the fab for plasma deposition and etching processes as well as deep UV lithography lasers used to pattern the smallest features in semiconductor chips. And increasingly, tools using small droplets of liquid argon are employed to clean debris from the smallest, most fragile chip structures.
Helium	He is the second lightest element and coldest liquid and is used in electronics manufacturing at hundreds of points in the fab for cooling, plasma processing, and leak detection.
Oxygen	O ₂ is used for growing oxide layers in etching. Ultra-pure liquid oxygen (LOX) can be provided on-site with less than 10 ppb impurities without the need for an external purifier.
Carbon dioxide	CO ₂ is used to support leading-edge immersion lithography, specialized cryogenic cleaning applications, and DI (deionized) water treatment.

SPECTRA-N on-site nitrogen supply volumes



NITROGEN — Linde pioneered commercial gas purification and liquefaction plants and has been the global leader ever since. Our SPECTRA-N series nitrogen generators are designed to scale with customer requirements and have the highest level of operational efficiency.



HELIUM — Linde manages the world's largest and most diverse collection of helium production, with sources located on five continents and aggressive investment in new sources for long-term supply security.



HYDROGEN — We offer both SMR and electrolysis plants for the on-site production of hydrogen and both meet our customers' purity and volume requirements.





Solar market

Adding value to the global solar industry through leading integrated gases and chemical solutions.

Solar manufacturers are looking for ways to improve yield and cell efficiency and lower manufacturing costs. This calls for a strong, reliable, and knowledgeable partner like Linde that offers dedicated solutions and a single point of contact for the wide range of specialist materials used in photovoltaic production processes.

Solar partner of choice

Linde's commitment to clean energy and our global gas and engineering capabilities make us the materials technology partner of choice for solar cell manufacturers on any scale and in any location. Our technologies and solutions help photovoltaic manufacturers move beyond grid parity to green parity by improving their carbon dioxide footprint and reducing cost per watt through innovative gas and chemical technologies.

Linde's offer for the solar industry

- An extended product portfolio, a response to the needs of our customers, and a solid supply chain with the ability to deliver our products to any place in the world
- Strong gas engineering competence and chemical delivery systems at the customer site
- Support for technology development with a know-how developed over many years in the photovoltaic industry and through working with several different partners such as equipment manufacturers and end users

Strong focus on technology development

Linde is pioneering new products and technologies to help the PV industry improve solar cell efficiencies and manufacturing productivity. As part of our commitment to the latest process technologies, we are currently driving the trend from wet to dry processing. Building on our expertise in thin-film silicon solar, our dry processing technologies are enabling smarter crystalline silicon manufacturing processes.

Linde participates in several technology consortia programs such as:

- PEPPER Project in thin film PV where Linde successfully implemented PECVD chamber cleaning using molecular fluorine and helped drastically reduce cleaning time
- EuroPlas Project, where Linde is using molecular fluorine for dry texturization of silicon wafers

Linde is also well-prepared for future technology transitions such as PERC and heterojunction cells, which use a wider portfolio of materials.

Heterojunction

Linde can supply all the gases necessary for the very promising technology of heterojunction, which can deliver very high efficiencies. From our development activities in thin film PV and the display industry, we have gathered in-depth knowledge on process and gas applications that are particularly suitable for heterojunction cell manufacturing. We can also work with you to help reduce costs, increase productivity, and further improve cell efficiency.

Solar portfolio and supply chain

As a global gas and material supplier, we leverage our global reach to offer the full range of gas and chemical products to support all crystalline silicon cell manufacturing processes. This includes ultra-pure bulk gases, electronic special gases in cylinder and bulk supply, and special and wet process chemicals. We have gathered incomparable expertise in a global supply chain over the years and are able to deliver products to any place in the world. As new cell manufacturing ramps in Southeast Asia and beyond, Linde is well positioned to provide a complete and secure supply chain in this area.

Bulk gases

Nitrogen (N ₂)
Hydrogen (H ₂)
Helium (He)
Oxygen (O ₂)
Argon (Ar)

Electronic specialty gases

Silane (SiH ₄)	Trimethylaluminum (TMA)
Ammonia (NH ₃)	Nitrous oxide (N ₂ O)
Fluorine (F ₂)	Carbon tetrafluoride (CF ₄)
Sulfur hexafluoride (SF ₆)	Phosphoryl chloride (POCl ₃)
Chlorine (Cl ₂)	Arsine (AsH ₃), diborane (B ₂ H ₆), and phosphine (PH ₃) mixes



Display market

Serving the display flat panel industry worldwide - supported by extensive gas infrastructure throughout Asia.

The manufacture of display flat panels calls for large-scale supply of ultra-pure gases. With dynamic growth in this competitive sector, manufacturers want the affordability, reliability, and flexibility of a gases partner like Linde that can deliver locally, but has the backing of a global supply chain.

Global reach

As a global supplier of the display flat panel industry, Linde has dedicated process gas production facilities in China, Korea, and Taiwan and a bulk gas support infrastructure throughout Asia. We also offer a comprehensive electronics specialty gases portfolio and provide on-site fluorine systems for chamber cleaning, which lowers manufacturing carbon footprints and decreases cleaning cycle time. In addition to the full range of gases required to manufacture display flat panels in all package sizes, we deliver unique value-added technical solutions and turnkey projects to help customers meet their environmental and cost targets.

Leading supplier of bulk and electronic specialty gases to China's flat panel display industry

Building on our position as the leading gas supplier to the Chinese electronics market, and growing with the display industry in China, we have become the leading supplier of bulk and electronic specialty gases to China's flat panel display industry. We have been awarded major bulk gas supply contracts by the three largest display manufacturers in China for their Gen 8.5 facilities to increase the cost effectiveness and environmental efficiency of their display manufacturing processes. We executed on-site and bulk gas projects for the first two Gen 8 TFT-LCD fabs in China.

These turnkey projects include the full gas infrastructure and supply of the actual gases. Benchmark projects such as these demonstrate our commitment to enable growth in the rapidly expanding display market through best-in-class gas technologies and innovations.

Linde's offer for the display industry

- Cost-effective bulk gas supply including large-scale on-site SPECTRA-N high-purity nitrogen generators, which are the most cost-effective and reliable way to supply ultra-pure nitrogen in the large quantities needed by display manufacturers. With gas impurity levels below 1ppb, the SPECTRA-N generator consumes less power than conventional generators and also provides excellent turn-down capabilities to meet facility ramp-up requirements.
- Dedicated comprehensive electronics special gases portfolio and global supply chains for the display industry
- New high-purity nitrous oxide (N₂O) gas facilities in China, Taiwan, and Korea to support the next generation of display technology
- On-site Generation-F fluorine generators for chamber cleaning, lower manufacturing carbon footprint, and peace of mind in supply security, especially for Gen 10 and larger manufacturing fabs

Linde team at China gas production facility



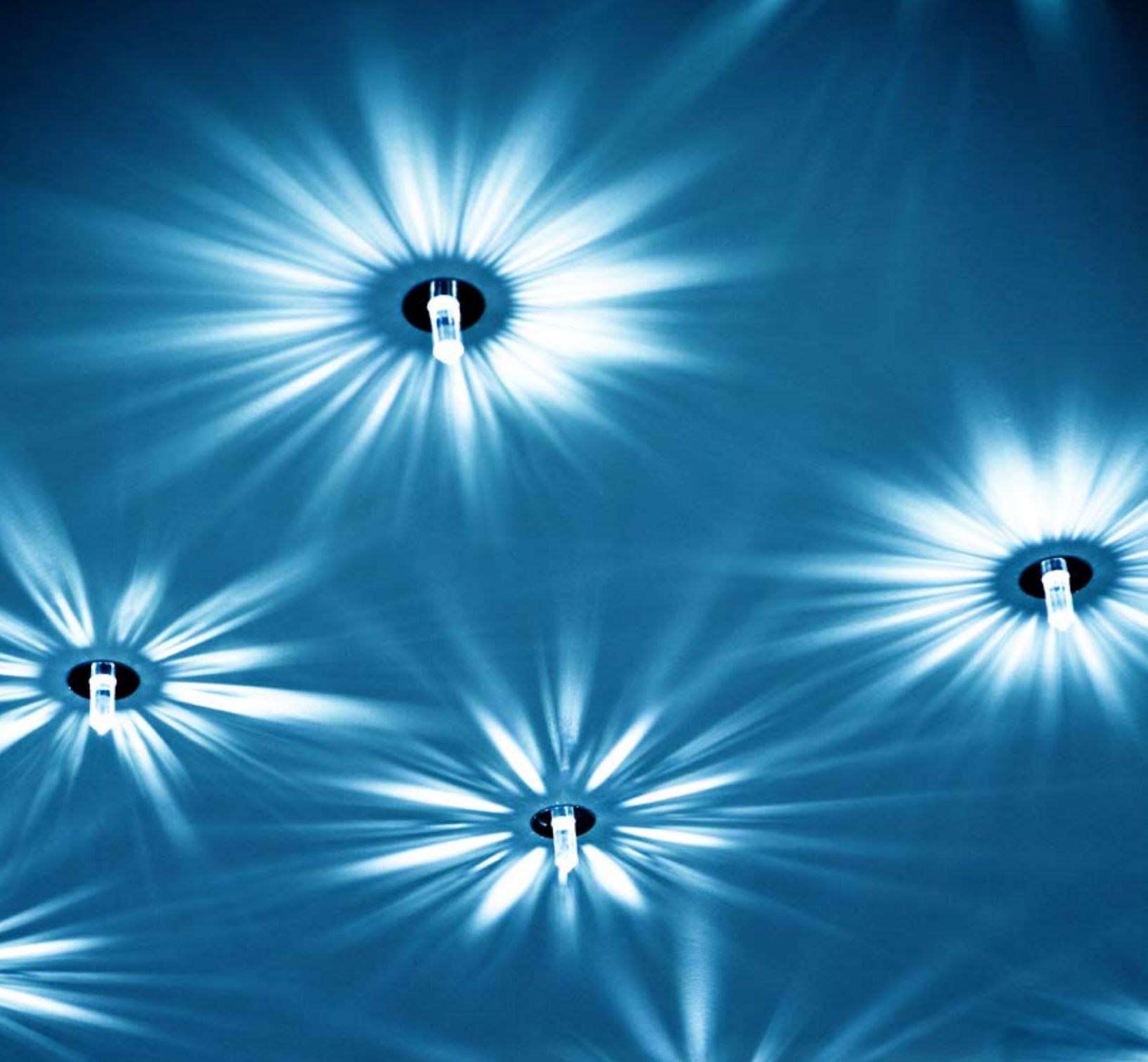
Gases for the display industry

Bulk gases

Argon (Ar)	Hydrogen (H ₂)
Carbon dioxide (CO ₂)	Nitrogen (N ₂)
Helium (He)	Oxygen (O ₂)

Electronic specialty gases

Ammonia (NH ₃)	Silane (SiH ₄)
Chlorine (Cl ₂)	Sulfur hexafluoride (SF ₆)
Nitrogen trifluoride (NF ₃)	Phosphine/hydrogen (PH ₃ /H ₂) mix



LED market

Offering the full range of high-purity bulk and special gases along with turnkey on-site facilities for maximum flexibility and efficiency gains.

The adoption of LED solid state lighting is growing rapidly, driven in particular by applications such as LCD TV backlighting and low-power general illumination. To accommodate this expanding market, LED manufacturers need large quantities of nitrogen, high-purity ammonia, hydrogen, and hydrides. They also need a flexible supply partner like Linde to support rapid, cost-effective increases in production.

Reliable partner and seamless product supply chain

Linde supplies the full range of bulk and electronic specialty gases required for LED manufacturing. As material requirements evolve, we are also committed to developing robust delivery solutions supported by a flexible and reliable supply chain for maximum productivity improvements.

- Linde has local production facilities of ultra-high purity ammonia in China, Taiwan, and Korea, where around 80% of global LED production capacity has been built.
- As a global gas supplier, we have established a network of nitrogen production and can deliver to our customers anywhere in the world.

On-site supply

We complement our electronic materials portfolio and global supply chain with turnkey capabilities for larger LED fabs, which include a full product portfolio—gas, engineering, and service. These on-site facilities ensure a continuous, monitored, and flexible supply of gas and reduce the complexity of dealing with multiple suppliers. Standardized and modular designs give you the added benefit of maximum cost efficiencies and reliability.

- On-site ammonia purifiers
- SPECTRA-N on-site nitrogen generators
- On-site high-purity hydrogen generators

Materials for LED solid state lighting manufacture

The following table shows the main bulk and electronic special gases we supply to LED manufacturers:

Bulk gases	Electronic specialty gases	
Nitrogen (N ₂)	Ammonia (NH ₃)	Tetrafluoromethane (CF ₄)
Hydrogen (H ₂)	Arsine (AsH ₃)	Nitrogen trifluoride (NF ₃)
	Boron	Sulfur hexafluoride (SF ₆)
	Phosphine (PH ₃)	Silane (SiH ₄)
	Phosphorus	

Other offerings for the electronics industry

Linde offers hardware and expert engineering and materials management services. We help to minimize downtime and risks by ensuring safe and smooth process flows and by regularly sharing our detailed gas and chemical knowledge.

Hardware

- Bulk special gas systems
- Gas cabinets and gas distribution manifolds
- Valve manifold boxes and panels

Services

- Turnkey design and engineering
- Total gas and chemical management
- Total materials management



Ultra-pure wet chemicals

We supply chemicals for electronic manufacturing through our joint venture Asia Union Electronic Chemical Corporation (AUECC), a leading supplier of wet process chemicals to high-tech industries worldwide.





On-site services

Linde offers a wide range of professional services to allow you to focus on your core business and keep operations up and running. These extend from on-site services such as turnkey design, installation services, and end-to-end management of your gas and chemical supply to systems and equipment for gas and chemical distribution and dispense.

We are where you are. Linde's global network of electronic special gas plants means we are local to both our customers and to other prime material suppliers. We offer you the expertise of our own production along with the ability to further source globally and comprehensively. Linde supplies in all package sizes to create the optimal logistics and supply solution.

Our commitment to quality and safety underwrites all that we do in Linde Electronics. We know our customers have the tightest material requirements and quality in production, supply, and dispense is essential in your success. Safety is our number one concern. We strive to protect the health and security of our employees, contractors, customers, and community and are stewards of our environment for those who come after us.

Linde Electronics.

Safety. Quality. Commitment. Expertise. Environmental Leadership.

Linde Electronics is the leading source worldwide for gases for the electronics market—semiconductor, solar, display, and LED.

Linde Electronics is part of The Linde Group, one of the leading gases and engineering companies in the world, with approximately 65,000 employees working in more than 100 countries worldwide. The company is committed to technologies and products that unite the goals of customer value and sustainable development.

Linde Electronics helps electronics companies achieve their goals through a strong focus on safety, quality and environmental leadership, its expertise, commitment to the industry through ongoing investments in processes, engineering, and on-site and localized solutions, a broad portfolio that includes environmentally sustainable solutions, rigorously controlled electronic specialty gases (ESGs), bulk and pipeline gases, equipment, and services, and through working closely with customers to better anticipate and meet their evolving needs.

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