

THE LINDE GROUP

Linde



On-site F₂ for sustainable manufacturing

Leading to a
cleaner world

Delivering sustainable chamber cleaning

Leadership in environmentally sustainable manufacturing is a pillar of the Linde Group philosophy, and it is our goal to drive improvements in sustainability in every industry we serve. Linde Electronics has pioneered the use of molecular fluorine (F_2) as a replacement for high GWP fluorinated cleaning gases, such as NF_3 and SF_6 , which are currently used to clean CVD chambers in the manufacture of semiconductors, flat panel displays and thin film solar panels.

Linde's proven technology for generating low pressure F_2 on-site and on-demand eliminates the need for large volume / high pressure storage and ensures safe, reliable and high purity supply.

Global Warming Potential of Greenhouse Gases (100 year GWP kg CO_2 eq)

F_2	NF_3	SF_6
0	17,200	22,800



Delivering performance



F_2 plasma as seen from the PECVD tool chamber window

High purity Fluorine gas is the highest performance cleaning gas available, improving productivity on CVD tools, reducing energy consumption and environmental impact, with ZERO Global Warming Potential.

F_2 cuts cleaning time by >50%, reduces tool downtime and improves line throughput by up to 10%

F_2 reduces the mass of cleaning gas required by 50%

F_2 reduces the power consumption of the plasma source by 60%

These benefits are realised due to the simple mechanism and low energy required to create F radicals compared to other Fluorinated gases.

De-bottlenecking

*NF_3 flow ~ 10% cycle time
 F_2 reduction in clear time > 50%
Cycle time saved ~ 5%*

*New line output =
 $40 \times 1.05 = 42 MW!!$*

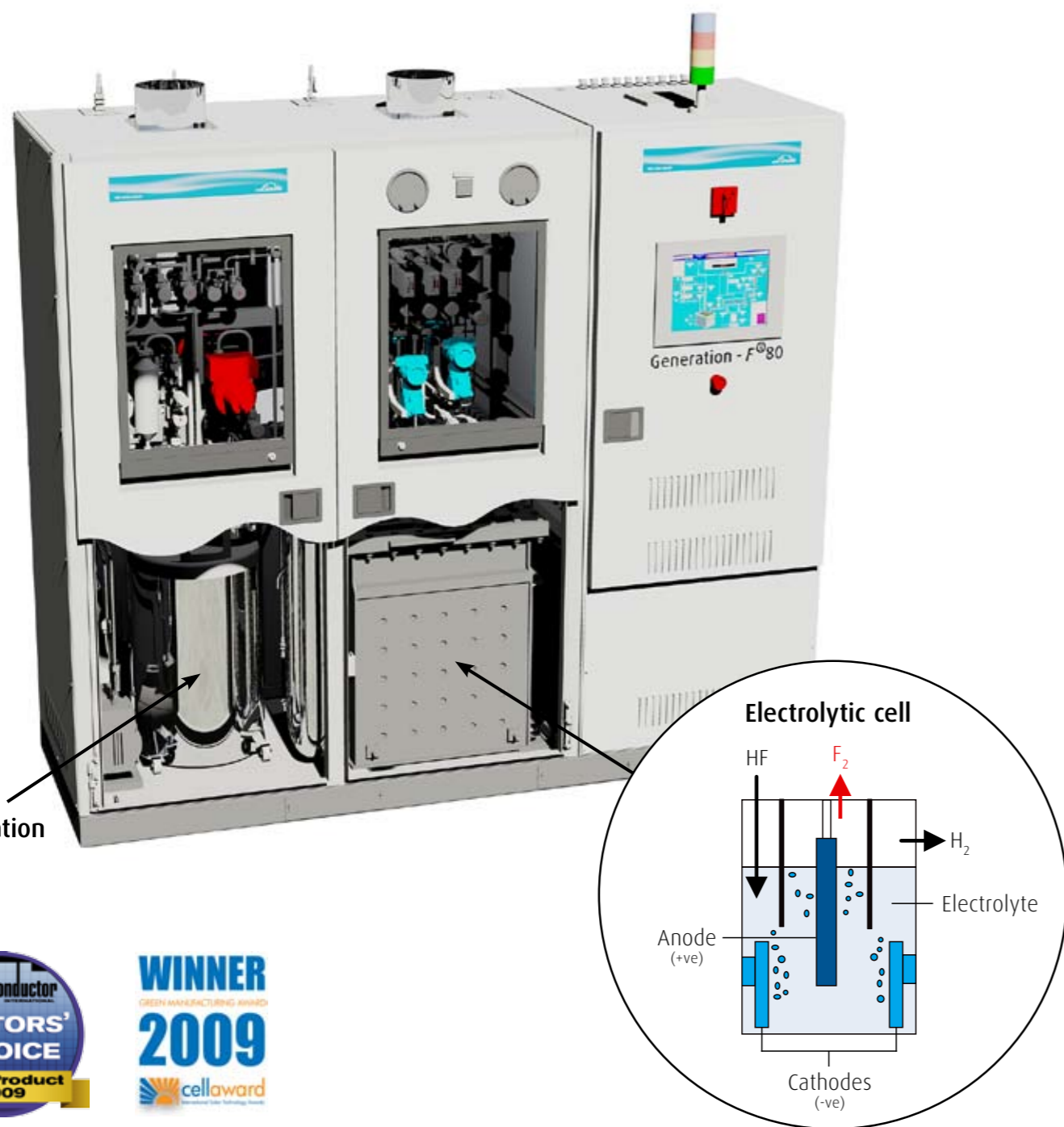
	F_2	NF_3	SF_6
Total Activation Energy	1 mol F from F_2 80 kJ	1 mol F from NF_3 281 kJ	1 mol F from SF_6 323 kJ
Bond Strength	F-F 159 kJ/mol	F_2N-F 248 kJ/mol	SF_5-F 326 kJ/mol
		$FN-F$ 278 kJ/mol	SF_4-F 222 kJ/mol
		$N-F$ 316 kJ/mol	SF_3-F 351 kJ/mol
		SF_2-F 264 kJ/mol	$SF-F$ 385 kJ/mol
		$S-F$ 339 kJ/mol	

Generation-F[®] a cleaner gas for a greener process

The award winning Generation-F[®] series from Linde provides 100% F₂ on demand for use in chamber cleaning applications.

The Generation-F[®] series of on-site generators are specifically designed to meet the exacting requirements of the electronics industry and have been supplying low pressure, high purity F₂ gas safely and reliably to CVD tools for more than 10 years. The series has been through extensive third party testing, is CE marked, Semi S2 Certified and OEM tested and approved.

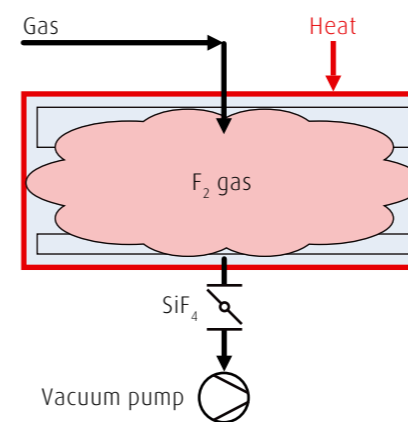
The series of Generation-F[®] generators are modular systems capable of meeting all flow, concentration and volume requirements from single tools up to large scale fabs.



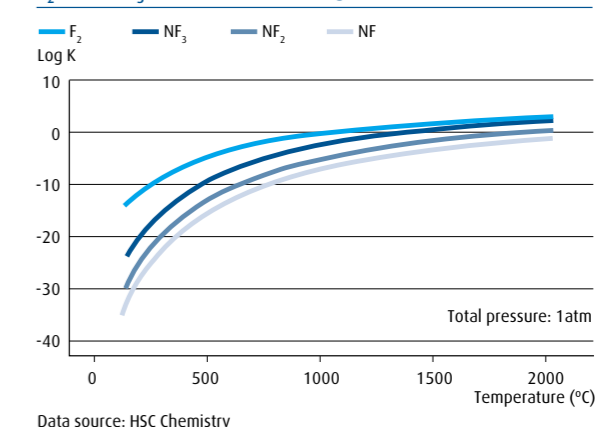
Delivering enabling technology

Thermal activation

Faster cleaning at lower temperatures than NF₃

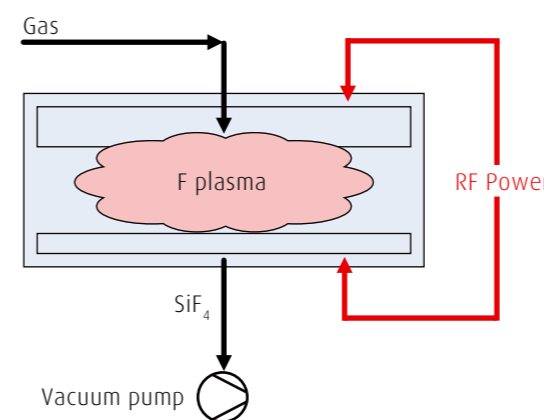


F₂ and NF₃ Dissociation Energies

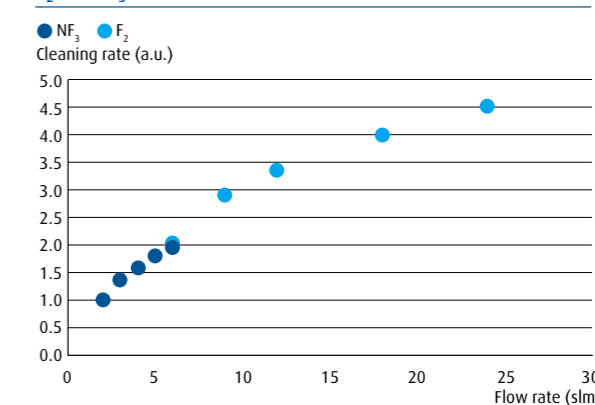


In-situ activation

Up to 5x faster cleaning; up to 50% less mass of gas required compared to NF₃

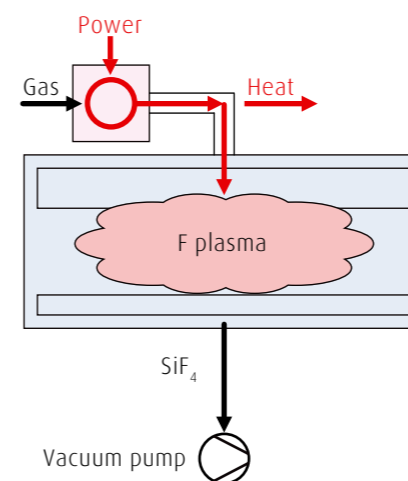


F₂ vs NF₃ Chamber Cleaning

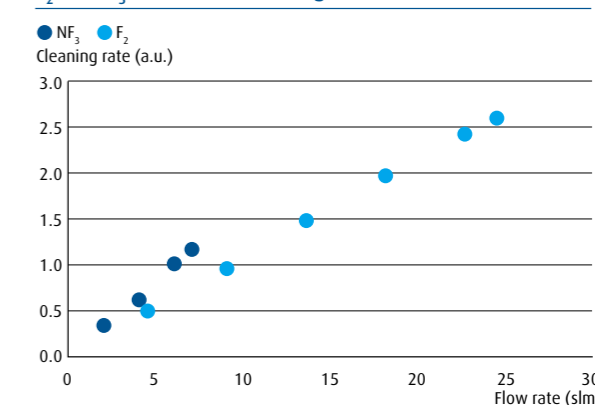


Remote plasma activation

Up to 4 x faster cleaning; up to 20% less mass of gas; up to 60% less power



F₂ vs NF₃ Chamber Cleaning



Delivering globally



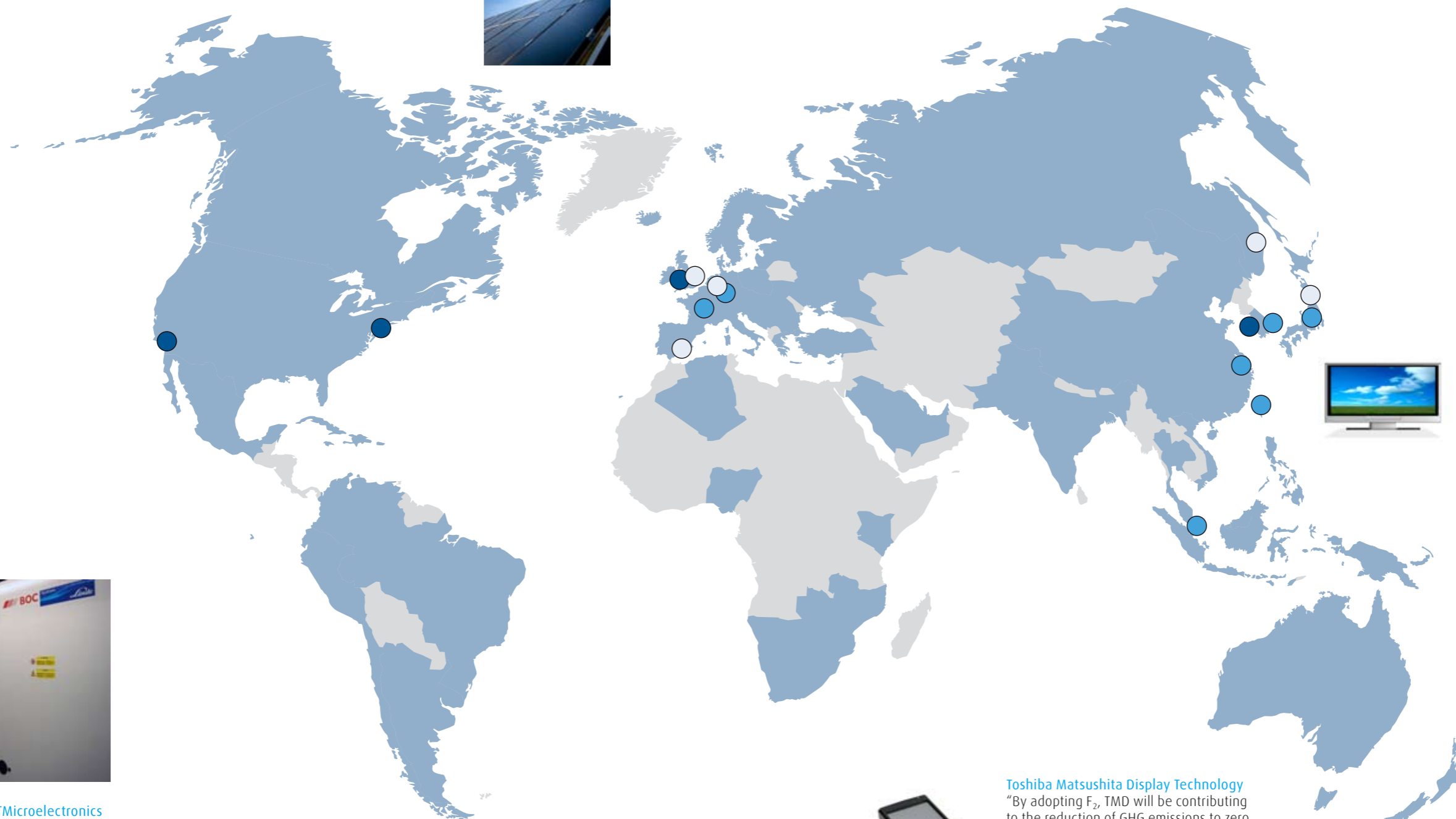
Malibu

"Not only does the F₂ cleaning process eliminate a major source of potential greenhouse gas emissions for our thin-film solar panels, it also speeds our processing and uses less material."



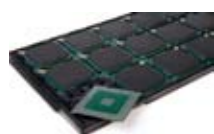
Hynix

"The convenience of fluorine generation is that it removes the need to check up on and change gas cylinders and has improved the safety of our operations. We hope the fluorine generation system will be extended to more processes."



LG Display

The LG Display 6th Generation TFT-LCD (thin film transistor-liquid crystal display) manufacturing facility in Gumi, South Korea, was the first of its kind in the world and they have used Linde fluorine generation from the outset. Linde continues to supply fluorine safely and reliably to the LCD industry.



STMicroelectronics

"We have directly reduced our carbon footprint at Crolles 300mm by eliminating cylinder deliveries. We are excited by the potential for even greater environmental efficiency by using the generation capacity in other cleaning applications."

One cylinder of HF provides the same amount of F₂ to the fab as 100 high pressure F₂ cylinders – significantly reducing maintenance workload, while the very low system pressure provides much greater safety for all STMicroelectronics engineers."

- Linde Electronics F₂ sites
- CVD customer F₂ installations
- Other customer F₂ installations
- Linde presence



Toshiba Matsushita Display Technology

"By adopting F₂, TMD will be contributing to the reduction of GHG emissions to zero, whereas with NF₃, zero gas emissions could not be achieved, even with detoxifying systems."



Linde Electronics. Innovation - Service - Leadership

Leading. Linde Electronics is part of the Linde Group, the leading gases and engineering group of companies, with around 50,000 employees working in around 100 countries worldwide. Our mission is to enable smarter, lower cost and more sustainable electronics manufacturing through innovative technologies and solutions.

We believe in the concept of zero accidents and incidents, striving to create a safe and effective working environment for our people and our customers. We wish to ensure long term customer satisfaction and loyalty by consistently providing products and services that meet each customer's expectations for quality. We develop and promote technologies, products and services that are environmentally sustainable.

To find out more about Linde Electronics, visit us online or send us an email:

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