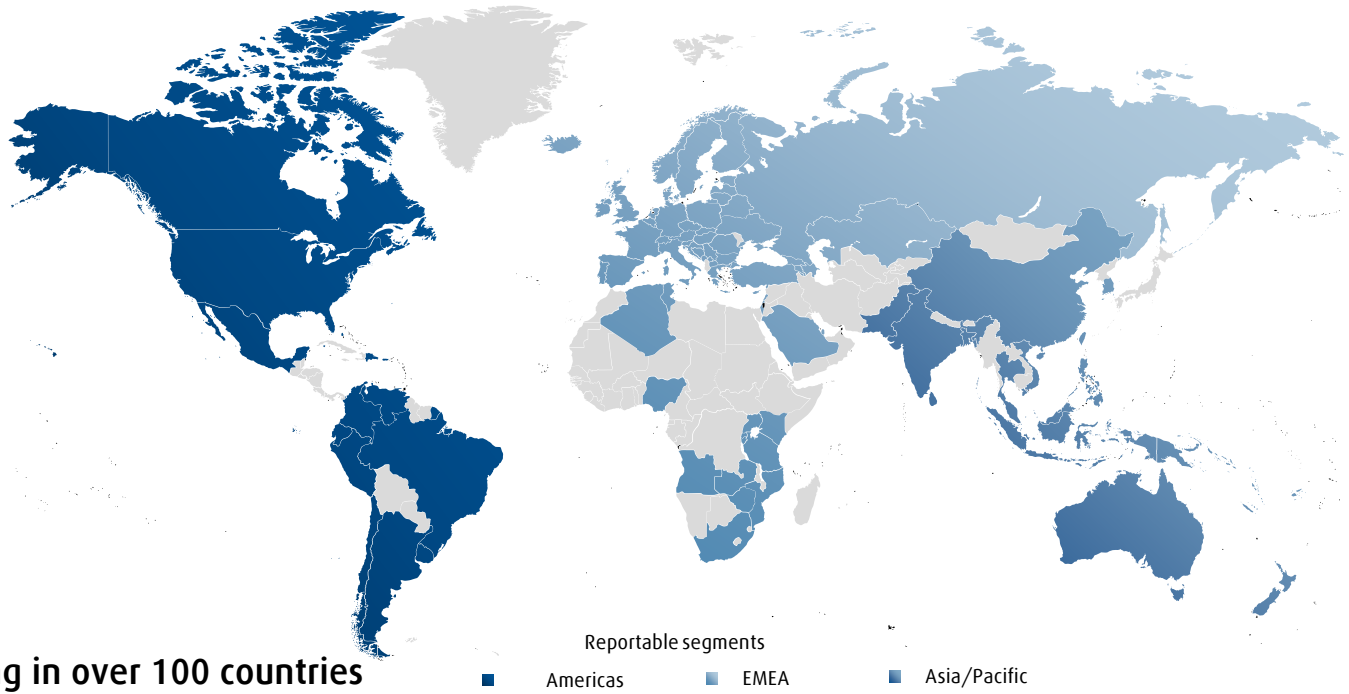
Integrating domestic and international electronic material solutions

Anshul Sarda, Vice President, Electronic Special Gases, The Linde Group
March 2018

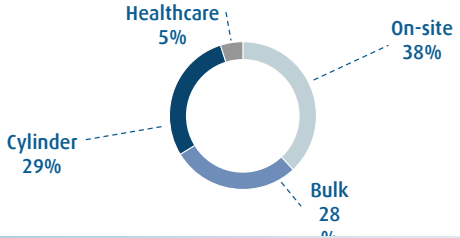
The Linde Group worldwide



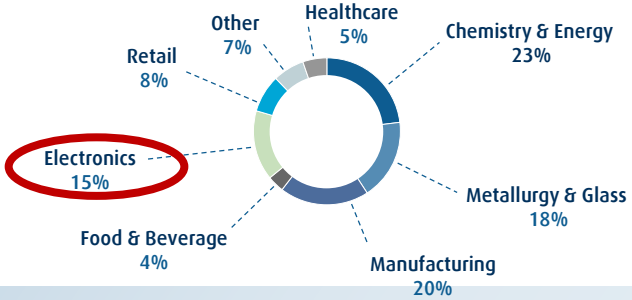
- **Operating in over 100 countries**
- **Revenue of 135 Billion RMB**
- **60,000 employees**

Linde Gases – Leading industrial gases company in APAC

Revenue split by product area



Revenue split by industry



- Strong position in major industrial clusters in Asia/Pacific
- Solid track record of revenue growth built on a diverse portfolio of leading customers

Company profile

Linde Electronics

- Leading in electronic gases
- Serving global top semiconductor, solar, display and LED customers
- Part of the Linde Group – an international industrial gas and engineering company

Linde LienHwa

- Leading in electronic gases
- Mainly serving top tier customers in Mainland China and Taiwan for over 30 years

Total electronic bulk and special gas solution provider with local expertise and global network adding value to customers' business

Linde LienHwa - Serving all of Asia with broad portfolio


LLH TW Headquarters

Linde LienHwa (LLH) is a 50:50 joint venture company within The Linde Group


LLH CN Headquarters

Leading electronics specialty gases supplier in Mainland China and Taiwan since 1984

Over **1,600** employees, **largest** industrial gases manufacturer in Taiwan with production , warehousing, and trading capabilities

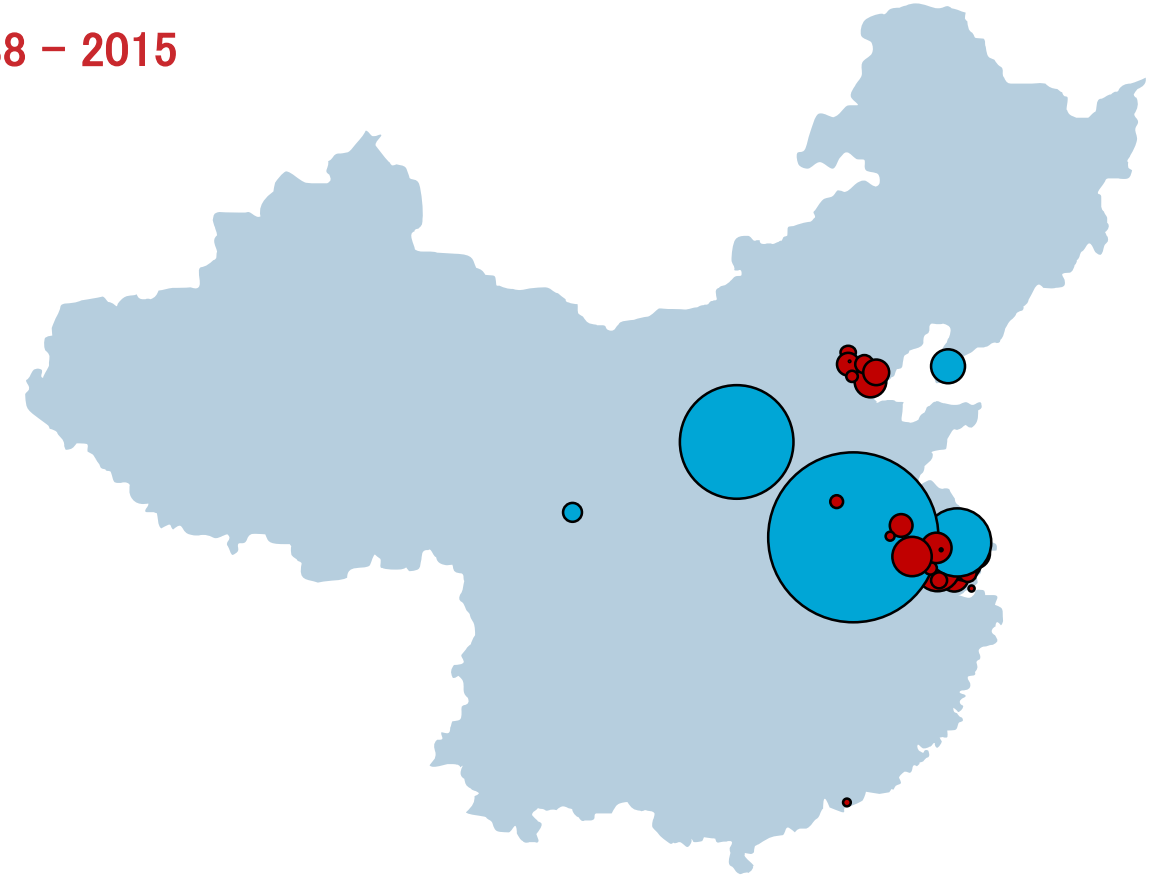

ESG Material Center

Leading bulk Gas market share in Mainland China and Taiwan
Leading Electronic special gas market share

Linde and the China semiconductor industry

Established wafer fabs

1988 – 2015



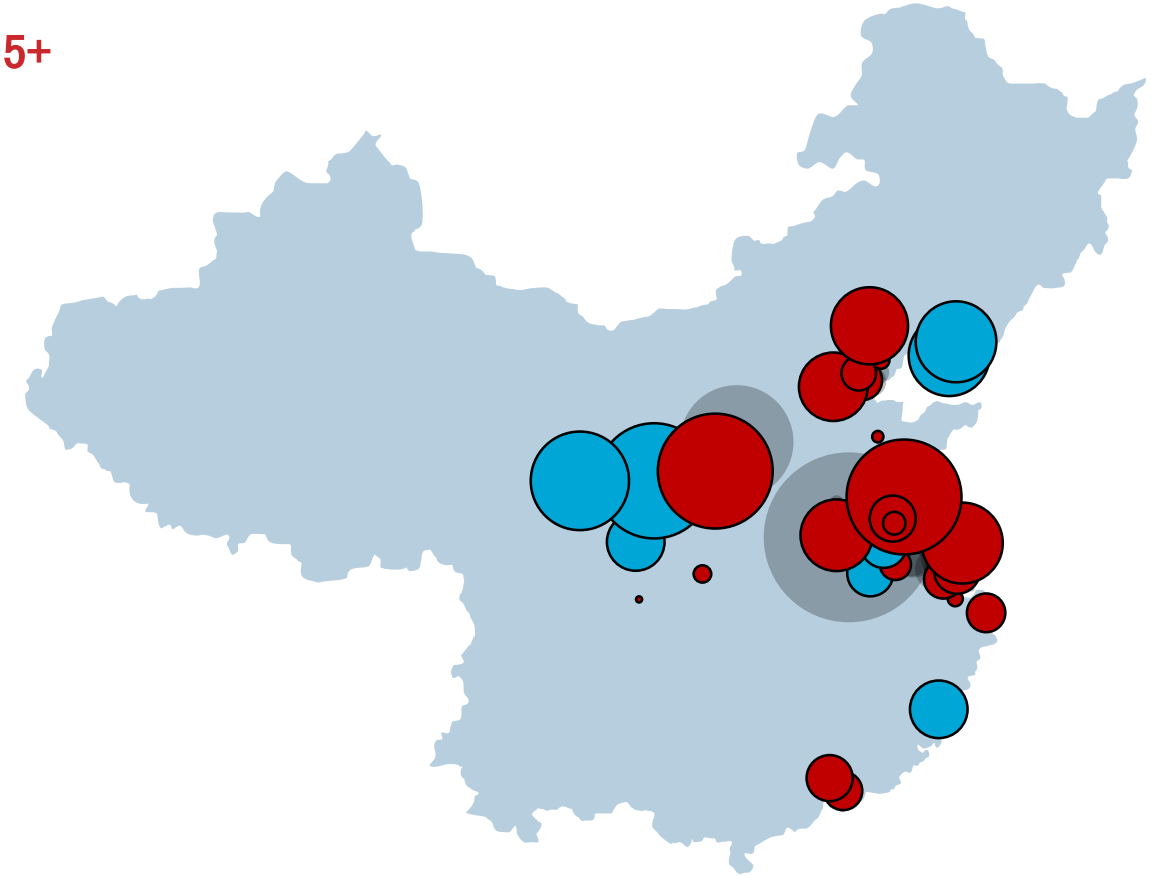
Relative Wafer Capacity

Domestic

Foreign

Announced wafer fabs

2015+

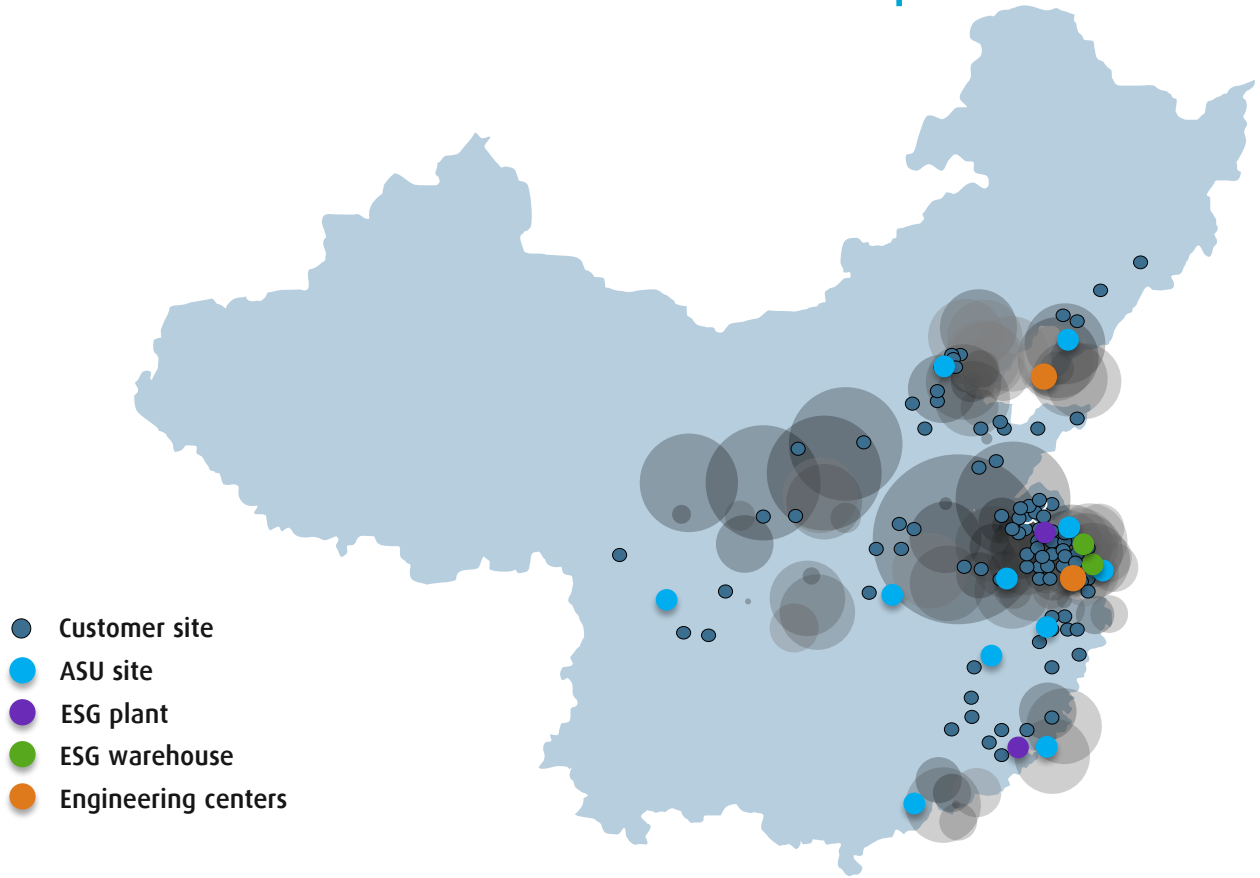


Relative Wafer Capacity

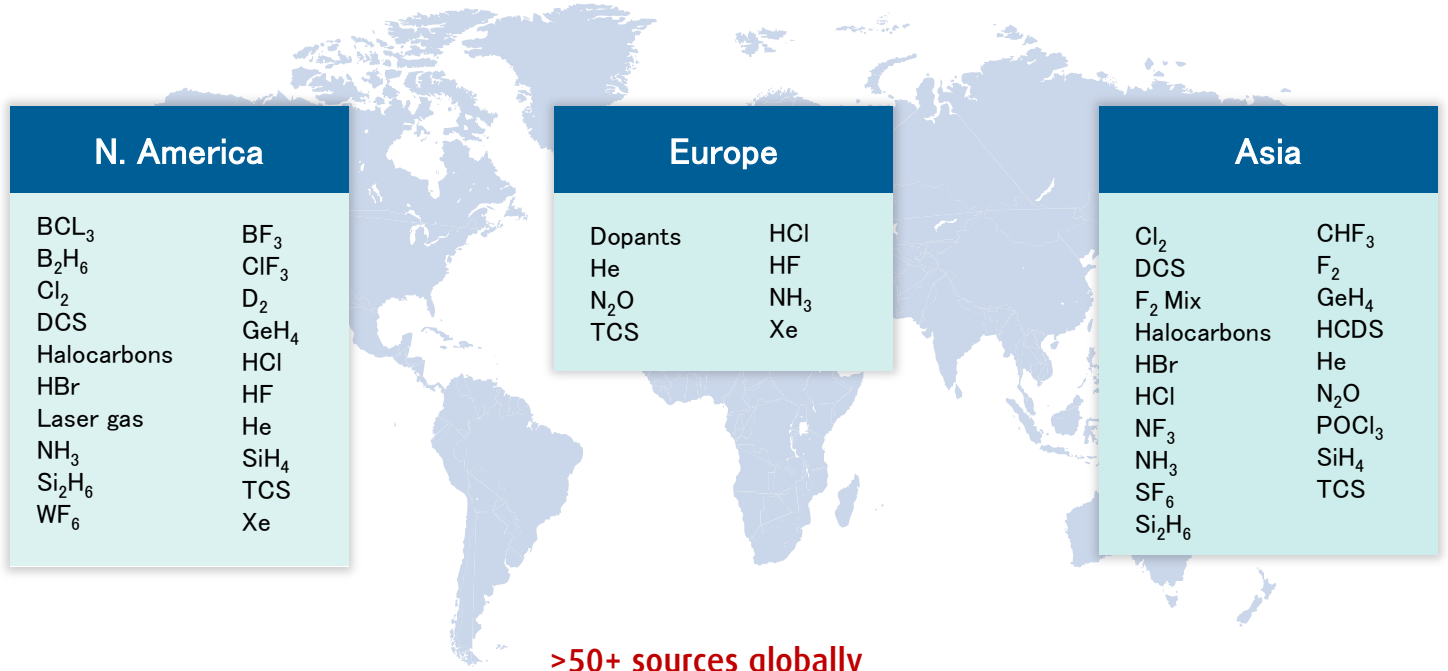
Domestic

Foreign

Linde Electronics mainland footprint



Linde global ESG supply network



N. America

BCL_3	BF_3
B_2H_6	ClF_3
Cl_2	D_2
DCS	GeH_4
Halocarbons	HCl
HBr	HF
Laser gas	He
NH_3	SiH_4
Si_2H_6	TCS
WF_6	Xe

Europe

Dopants	HCl
He	HF
N_2O	NH_3
TCS	Xe

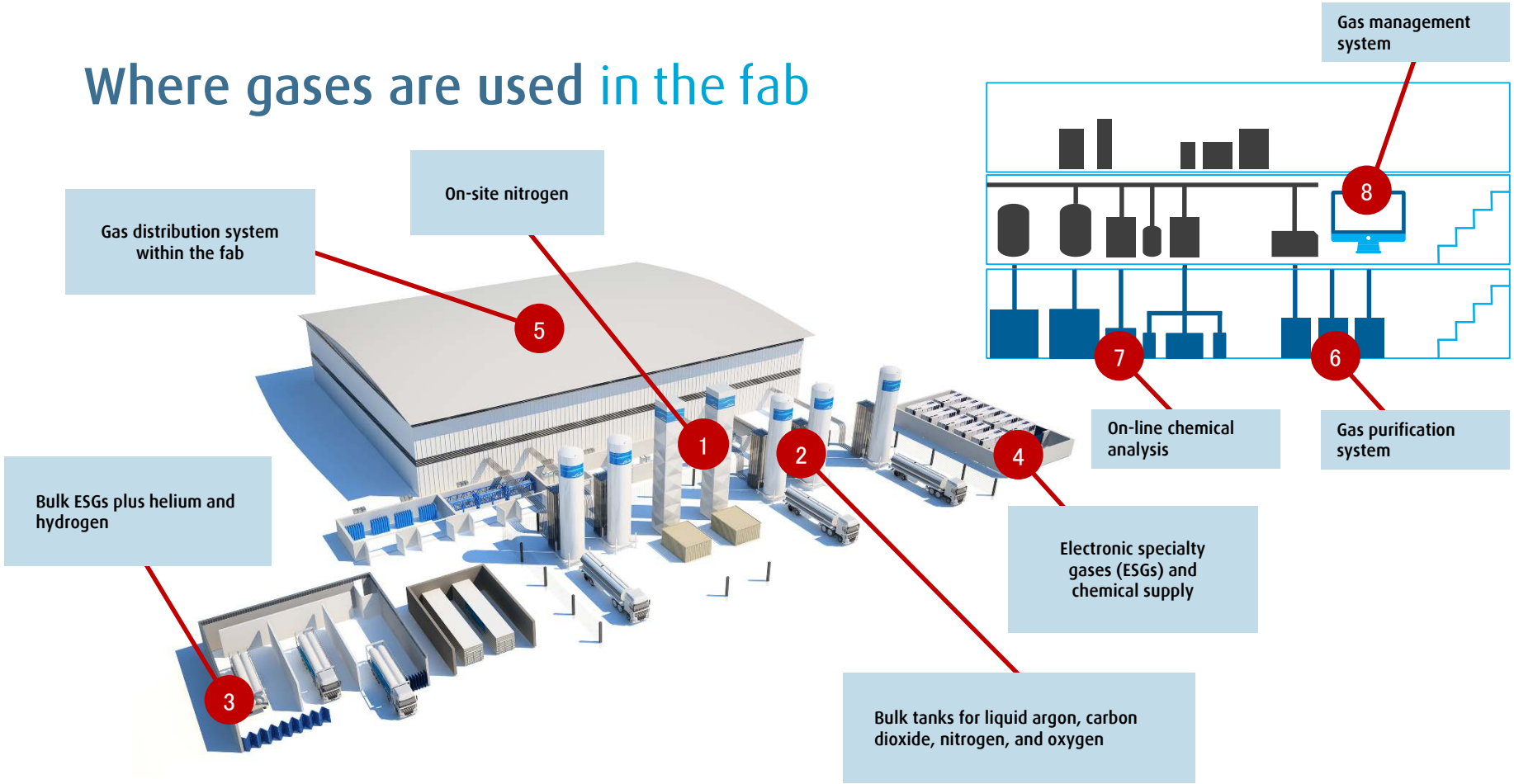
Asia

Cl_2	CHF_3
DCS	F_2
F_2 Mix	GeH_4
Halocarbons	HCDS
HBr	He
HCl	N_2O
NF_3	$POCl_3$
NH_3	SiH_4
SF_6	TCS
Si_2H_6	

>50+ sources globally

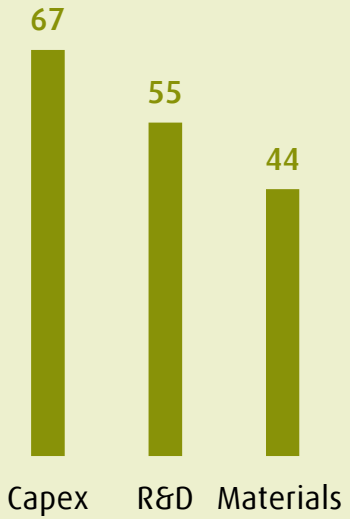
Why are gases important to semiconductors?

Where gases are used in the fab

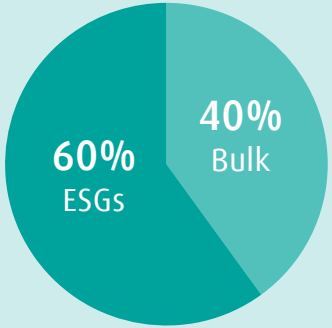


Material and gases in global electronics manufacturing

Relative semiconductor spend $B



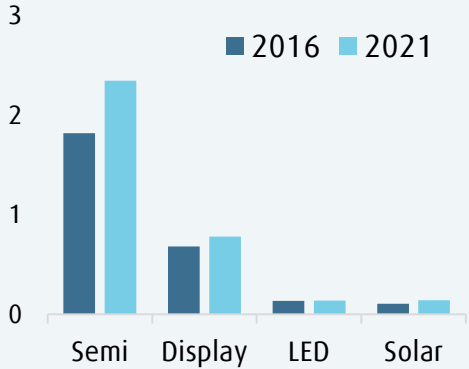
Electronic gas market $5B



Bulk gases

Nitrogen
Oxygen
Argon
Hydrogen
Helium
Carbon dioxide

Electronic special gas market $3B

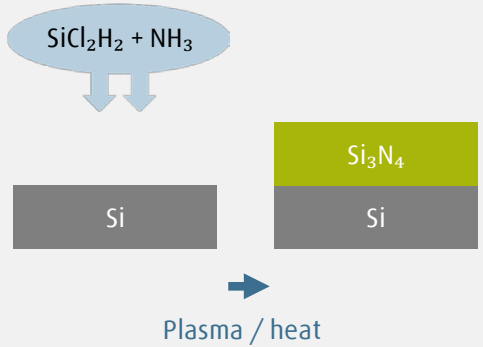


Top 10 ESGs

N_2O
WF_6
PH_3
SiH_4
C_4F_6
Laser
(Ne, Ar, Xe, F_2)
NH_3
NF_3
HCl
Si_2H_6

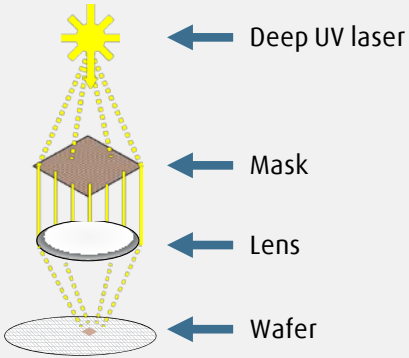
Examples of key processes that use ESGs

Deposition



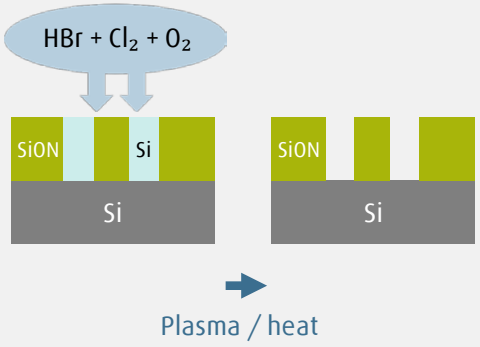
Nitrogen gases: NH_3, N_2O
Silicon gases: SiH_4, Si_2H_6, TCS, HCDS, TMS
Oxygen: O_2
Tungsten hexafluoride: WF_6
Germane: GeH_4

Lithography



Laser gases: 95+% Ne, with Ar, Kr, and F_2
Carbon dioxide: CO_2
Hydrogen: H_2

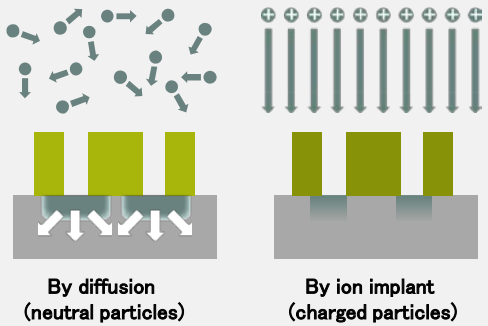
Etching



Fluorocarbons: CxHyFz CF_4, C_2F_6, C_3F_8, C_4F_8, C_5F_8, C_4F_6, CHF_3, CH_2F_2, CH_3F, C_2HF_5
Sulfur hexafluoride: SF_6
Halides: HCl, Cl_2, HF, F_2, HBr, ClF_3, XeF_2
Oxygen: O_2

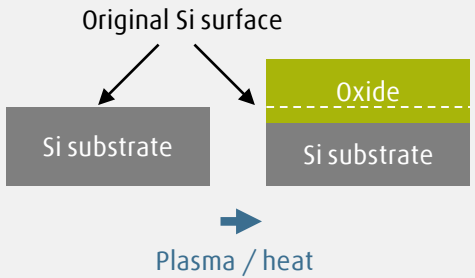
Examples of key processes that use ESGs

Doping



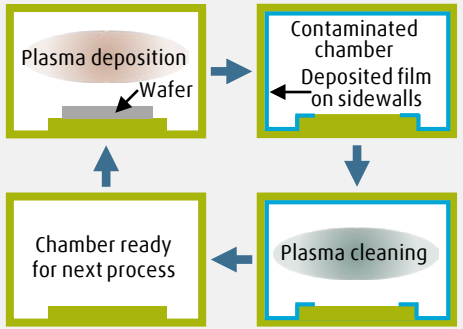
Hydrides: AsH_3, BF_3, B_2H_6, PH_3, GeH_4, Ge_2H_6

Annealing



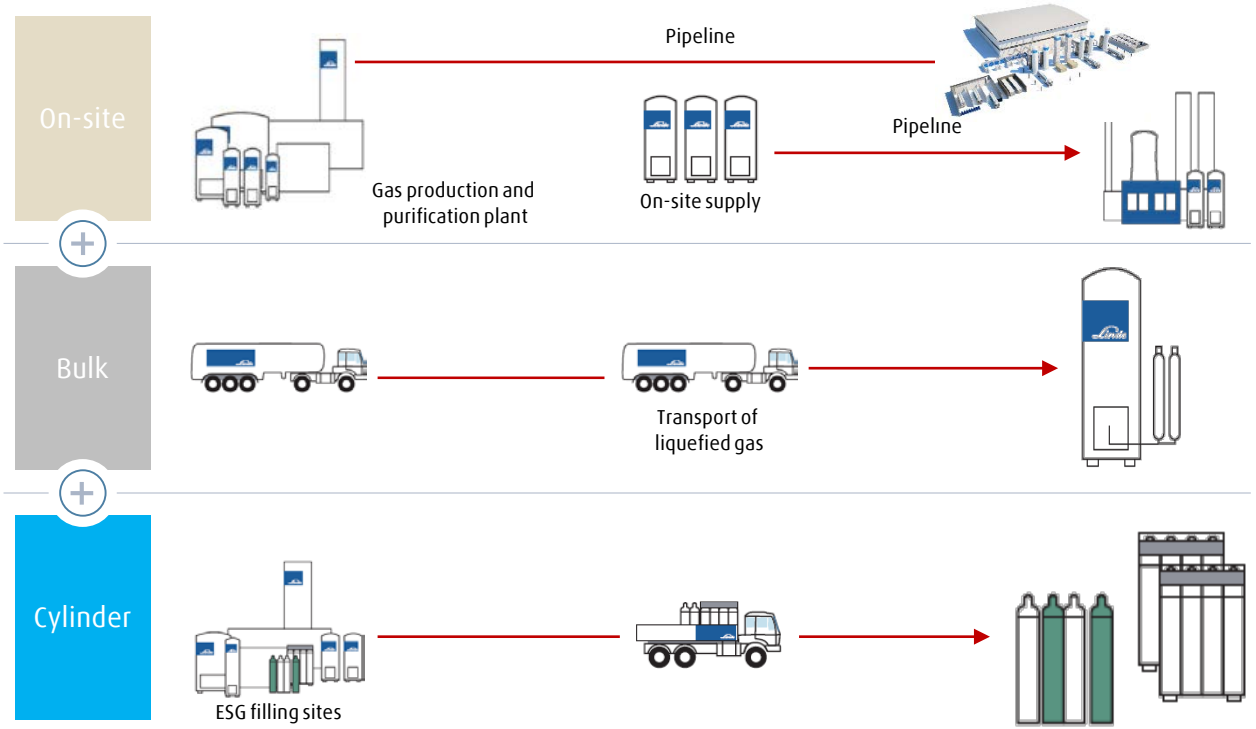
Oxygen: O_2
Hydrogen: H_2
Argon: Ar

Chamber Cleaning



Nitrogen trifluoride: NF_3
Other fluoride gases: CF_4, C_2F_6, C_4F_8, ClF_3, SF_6
Chloride gases: HCl, Cl_2
Fluorine: F_2

Gas supply model



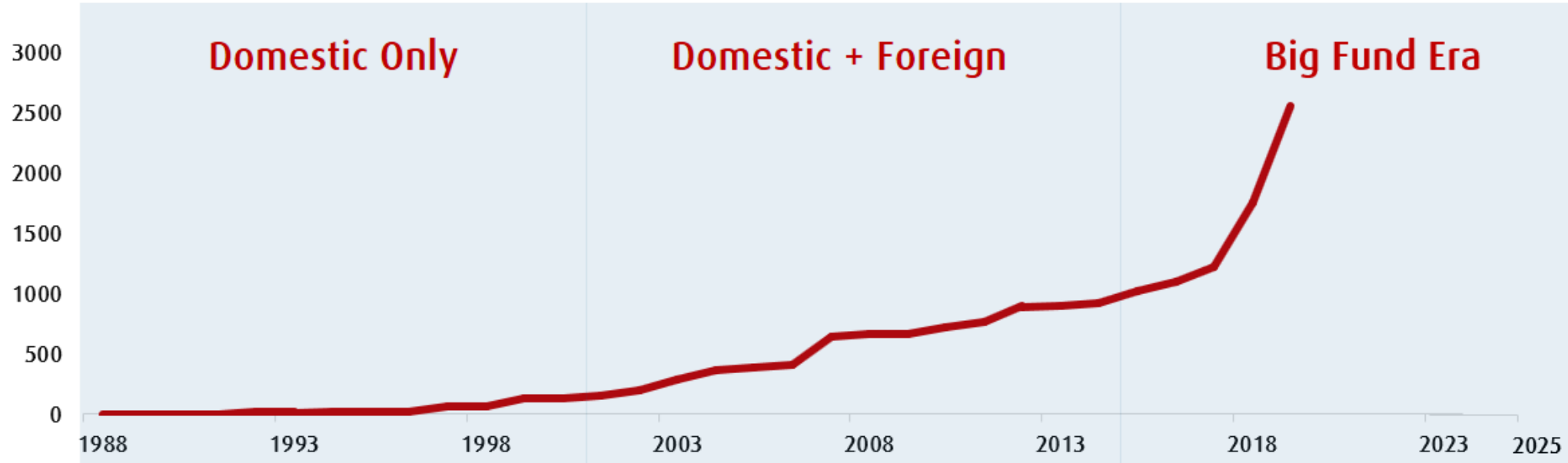
China semiconductor industry requirements

30 Years of mainland China semiconductor industry

Capacity growth and technology advancement

Cumulative MSI/year in China

MSI = millions of square inches of silicon



	Domestic Only	Domestic + Foreign	Big Fund Era
Capacity	small fabs for domestic/military purposes	larger but isolated fabs	mega fabs and clusters of investment
Technology	many generations behind leading-edge	foreign leading-edge + domestic-foreign JVs several generations behind leading-edge	sustained government support for domestic leading-edge technology

China semiconductor industry may be young...
But customers have same requirements

Quality

Secure supply

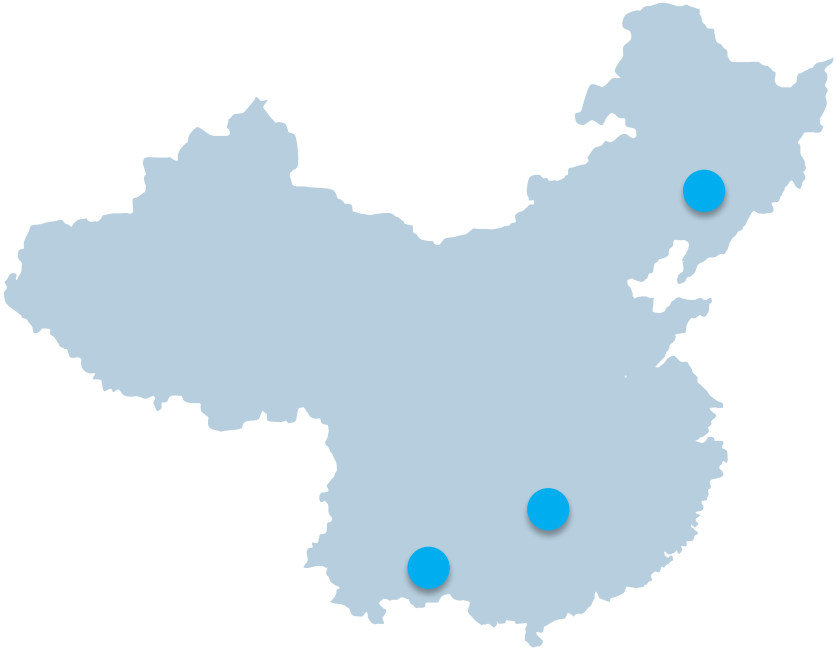
Expertise

Between the variability of the raw material source…

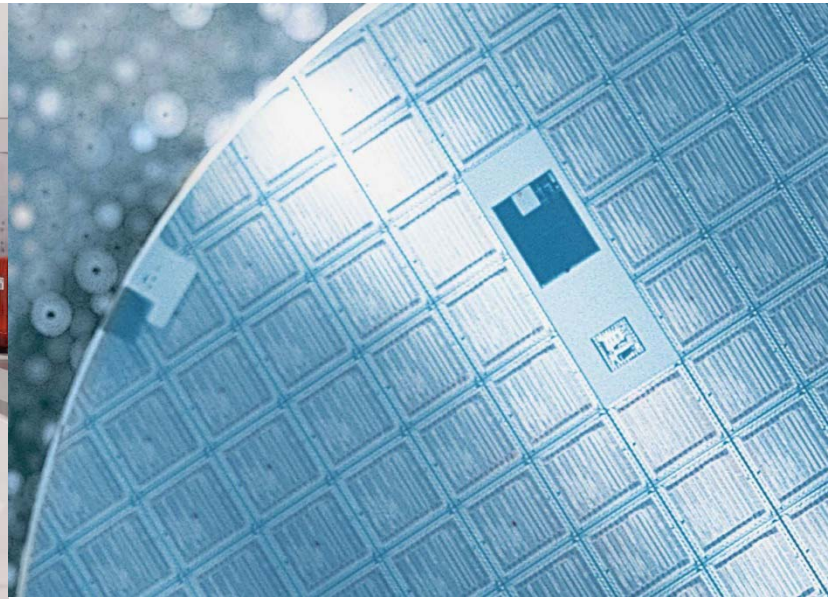
Liaoning Fluorspar:
HF, NF_3, SF_6, CF_4, etc.

Guangxi Tungsten:
WF_6, WCl_5

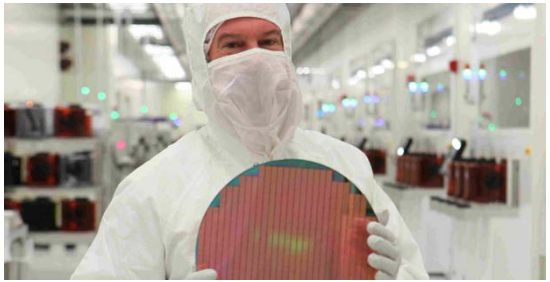
Yunnan Germanium:
GeH_4, Ge_2H_6



...and the precision of manufacturing

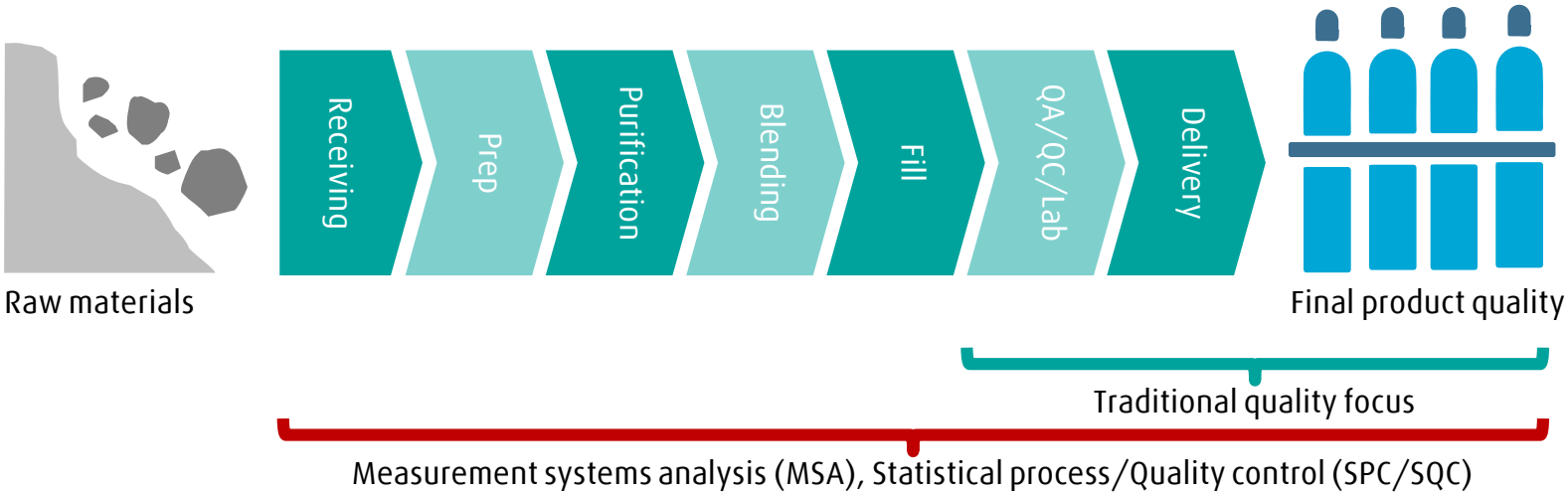


Material suppliers like Linde are the quality gatekeepers

Source	Quality	Use
		
		

Managing supply chain determines quality

Measure at each step, prevent defects, continuous improvement

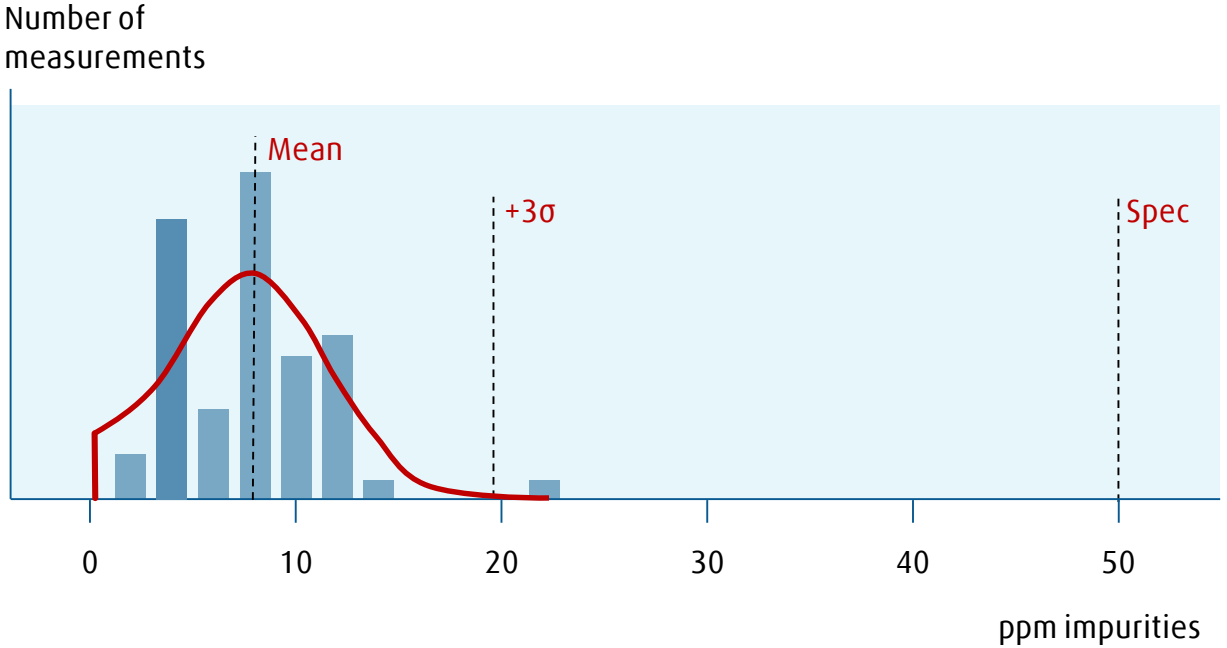


Quality: Customers are driving tighter requirements

Customers
Expect Linde to meet purity specifications and control limits

Are even more concerned about unknown and uncontrolled impurities

Example
Specification: 50 ppm
Control limit: 20 ppm
Mean: 8 ppm



For bulk products, our customers see quality analysis in real time

Quality: local and consistent

Copy-exact procedures to produce consistent results

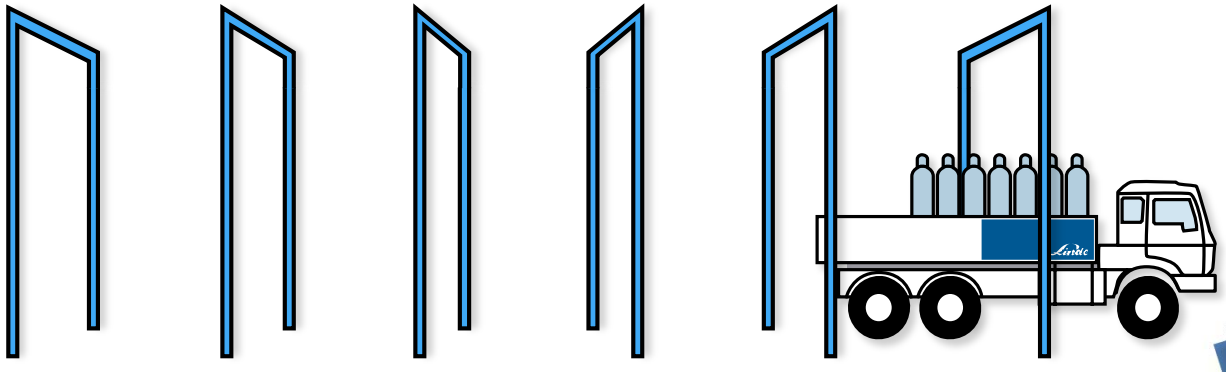
Suzhou Electronics Facility

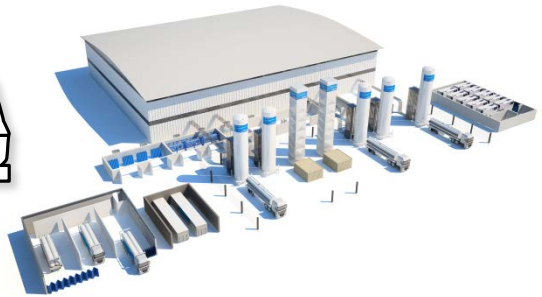
Taichung Electronics Facility

Delivering quality requires control across the full supply chain

Material providers like Linde are the quality gatekeepers

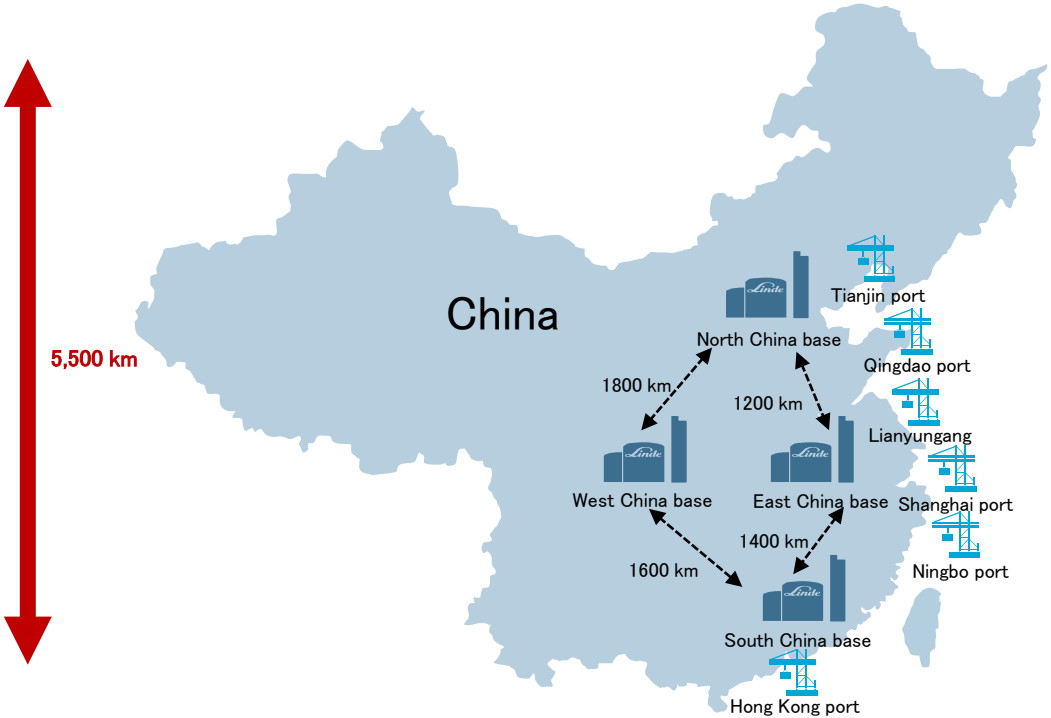
Raw materials | Chemical production | Purification | Blending | Analysis | Distribution



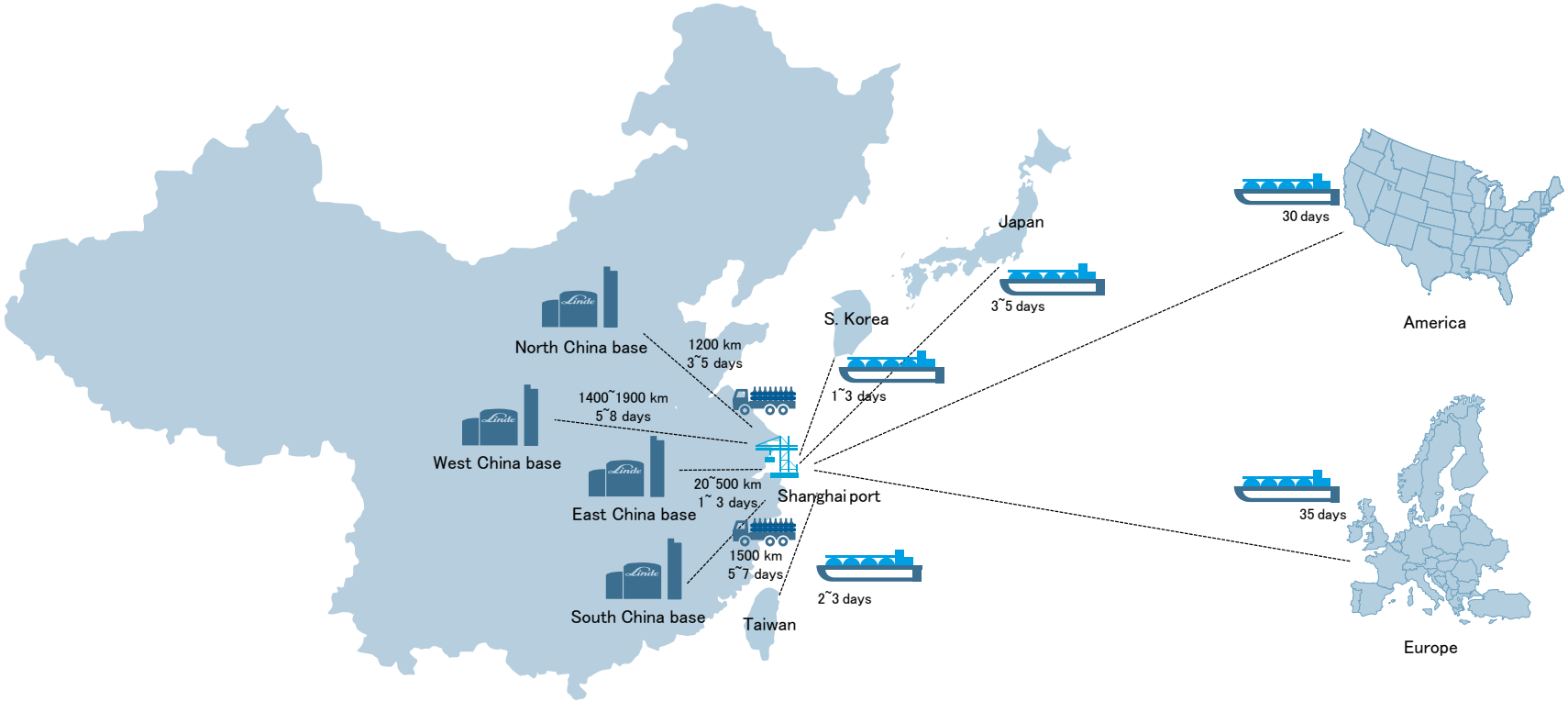


China ESG supply chain

China ports

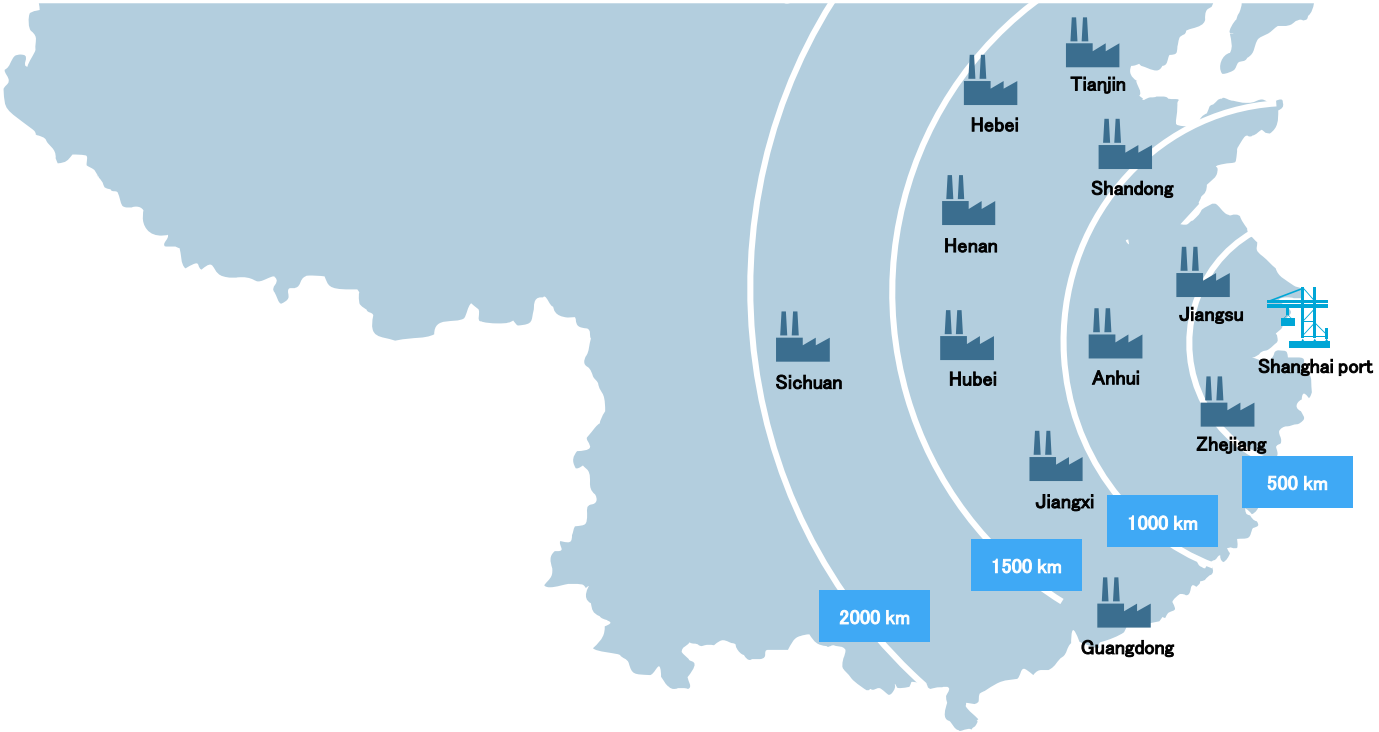

5,500 km
China
North China base
Tianjin port
Qingdao port
Lianyungang
Shanghai port
Ningbo port
1800 km
1200 km
West China base
East China base
1400 km
1600 km
South China base
Hong Kong port

Importing electronic materials into China



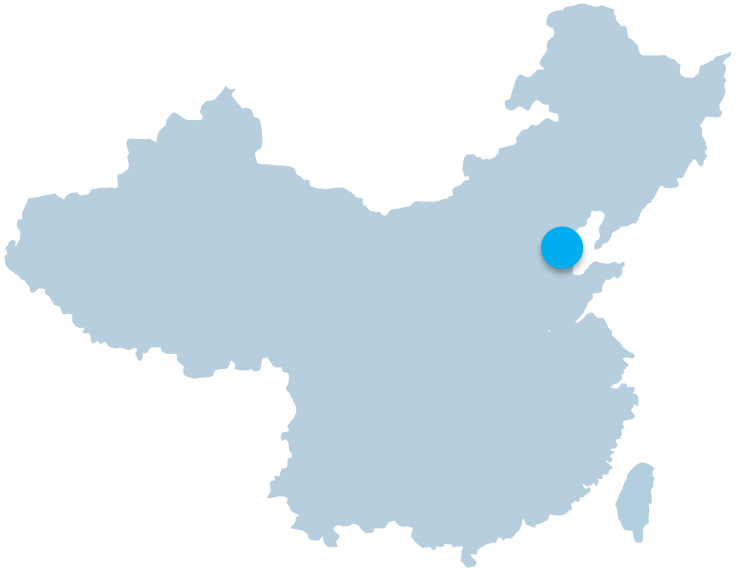
Electronic material supply into China takes 10 – 50 days.

China raw material processor locations



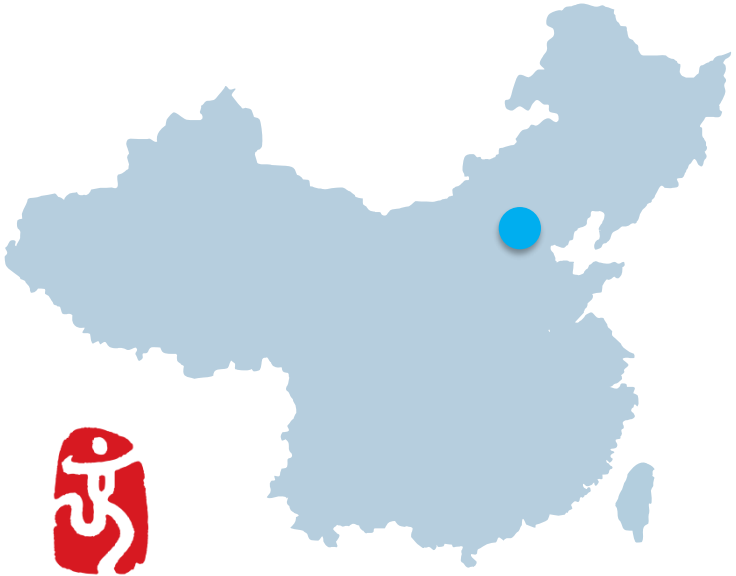
Major supply disruptions can change how we do business

Tianjin Port Explosion: 2015



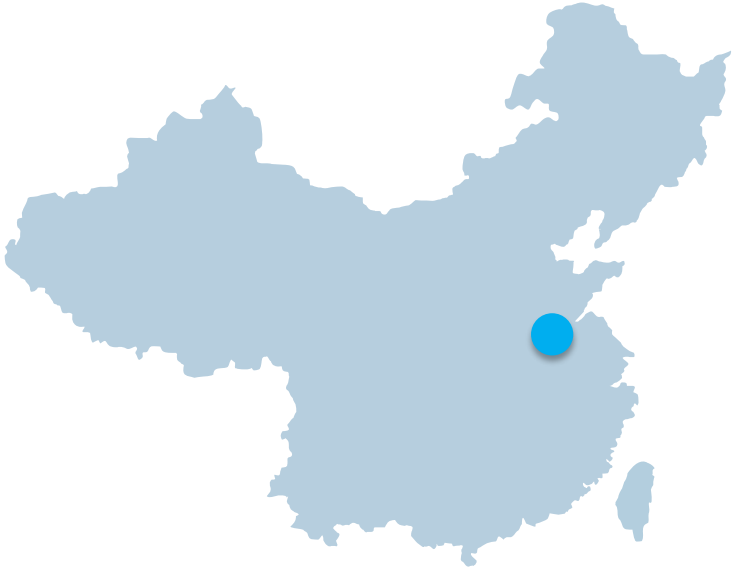
Major supply disruptions can happen for positive occasions

Beijing Olympics: 2008



Major supply disruptions can happen when just a few important people meet

G20 Summit: 2016



Long-term success for materials suppliers

Long-term success is integrating global expertise

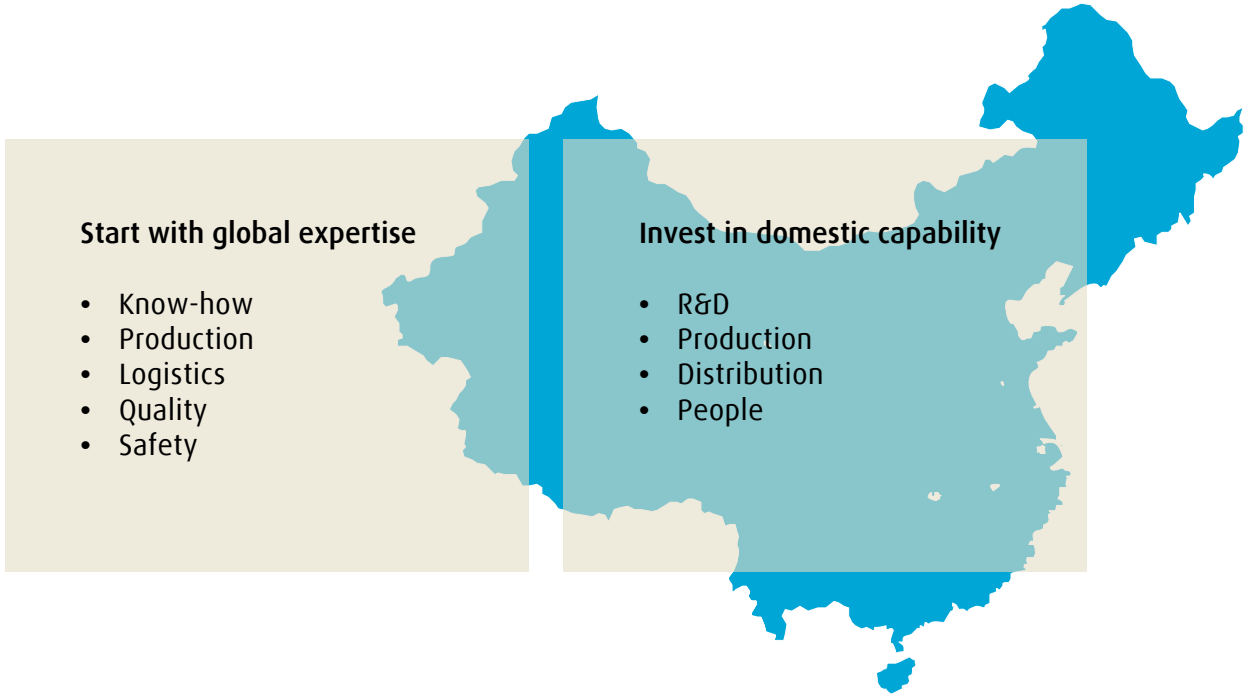
Local partner. Global expertise.

Start with global expertise

- Know-how
- Production
- Logistics
- Quality
- Safety

Long-term success is integrating global expertise

Local partner. Global expertise.



Long-term success is integrating global expertise

Local partner. Global expertise.

Start with global expertise

- Know-how
- Production
- Logistics
- Quality
- Safety

Invest in domestic capability

- R&D
- Production
- Distribution
- People

Partner with local raw materials suppliers

- Implement quality standards
- Secure supply chain

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