Critical materials within Semiconductor industry

Pascal ROQUET
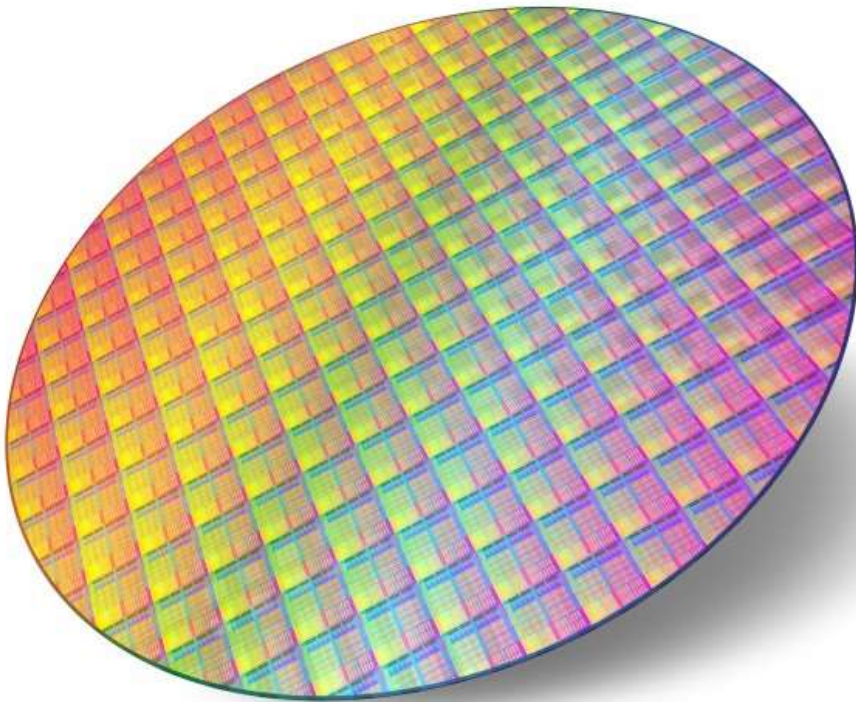
SUSTAINABLE TECHNOLOGY by *ST*

ST life.augmented

May 2019

Agenda

● ST who we are

● Materials in Semiconductor Industry

● Critical materials & gases

● Product Stewardship

STMicroelectronics

- Among the world's largest semiconductor companies
- Serving over **100,000** customers across the globe
- 2018 revenues of **$9.66B,** with year-on-year growth of **15.8%**
- Listed: NYSE, Euronext Paris and Borsa Italiana, Milan
- Signatory of the United Nations Global Compact (UNGC), Member of the Responsible Business Alliance (RBA)

- **~46,000** employees worldwide
- **~ 7,400** people working in R&D
- **11** manufacturing sites
- Over **80** sales & marketing offices

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As of December 31, 2018

- Research & Development
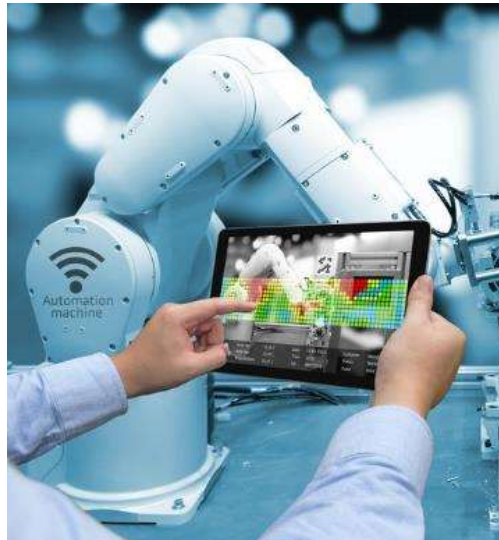- Main Sales & Marketing
- Front-End
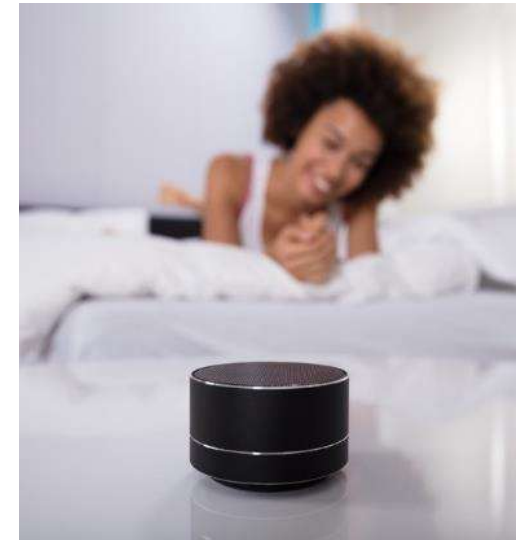- Back-End

Where You Find Us

Making **driving** safer, greener and more connected

Enabling the evolution of **industry** towards smarter, safer and more efficient factories and workplaces

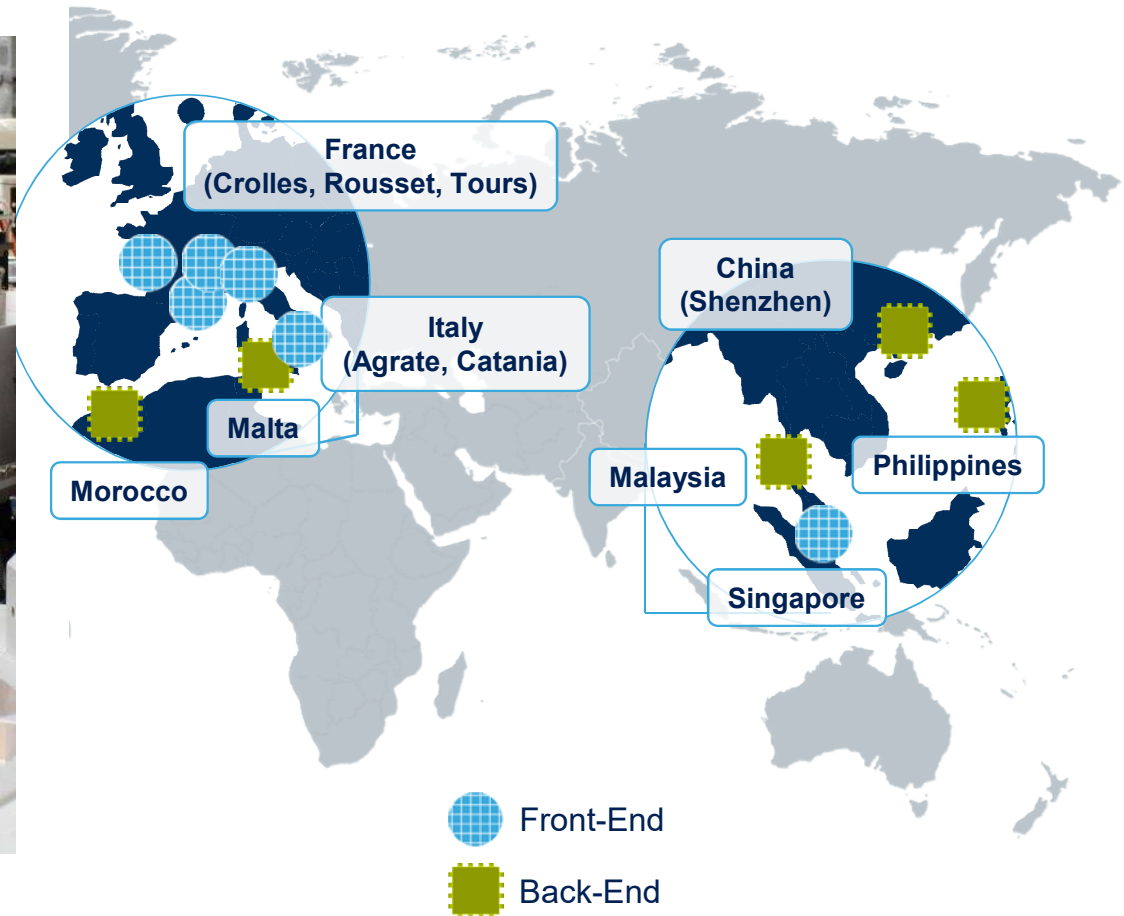Making **homes & cities** smarter, for better living, higher security, and to get more from available resources

Making everyday **things** smarter, connected and more aware of their surroundings

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Flexible & Independent Manufacturing

France
(Crolles, Rousset, Tours)

Italy
(Agrate, Catania)

Malta

Morocco

China
(Shenzhen)

Malaysia

Philippines

Singapore

Front-End

Back-End

Microelectronics is about ...

Integrated circuit

Back-End

Chip with connection

Front-End

Chip without connection

Wafer containing x000 chips

4x4 µm²

metallization

M 1   M 1   M 1
contact
50 nm
500x500 nm²

Transistor
50 nm
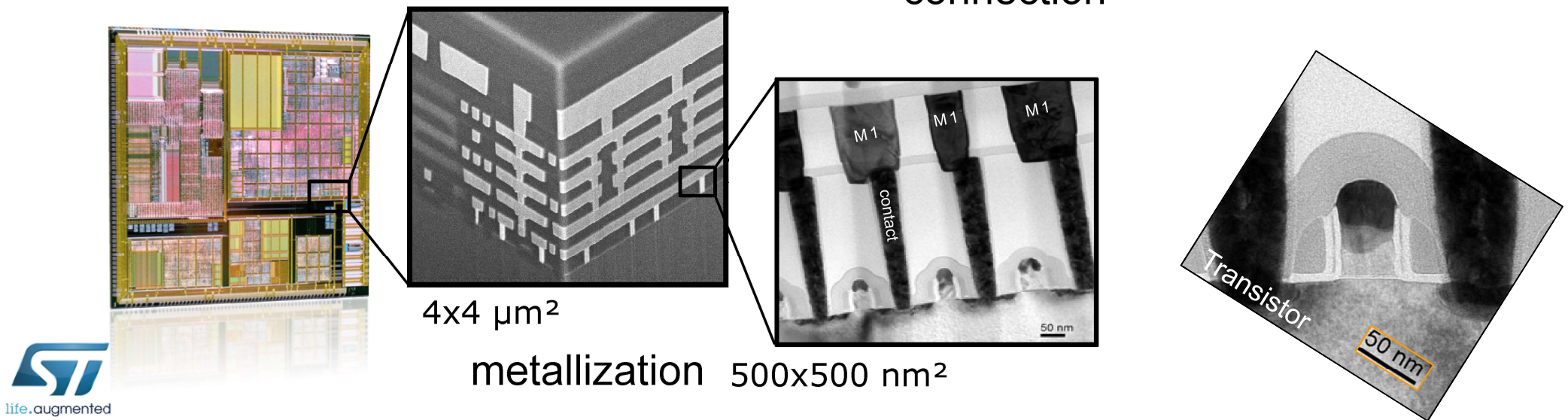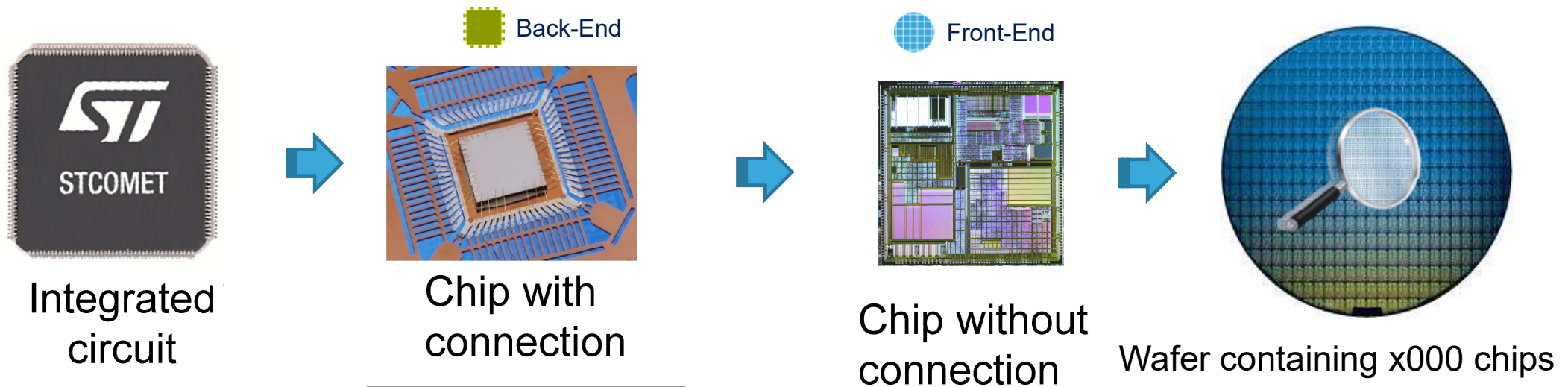
Crolles Fab
(15km from Grenoble)

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Sustainability is about....

Creating value and minimizing risks through effective management of
economic, environmental and social impact to ensure long-term business success.

- **Creating business values**
  - **Developing leading responsible products for an augmented life**
  - Promoting high standards of integrity and business conduct
  - Effective governance of our strategies and ambitions

- **Engaging and developing people**
  - Ensuring health and safety at work
  - Respecting and promoting people rights
  - Developing competencies and diversity

- **Supporting customers, investors and suppliers**
  - **Effective supply chain to serve all customers, minimizing execution risks and impacts**
  - **Taking into account the environmental, social and economical impacts in our decisions**
  - **Reducing water, energy and chemical consumptions for continuous efficiency improvement**

WE LIVE OUR VALUES: People, Integrity, Excellence

WE PUT PEOPLE FIRST

WE IMPROVE EVERYBODY'S LIFE

WE PROTECT THE ENVIRONMENT

TOGETHER, WE SHAPE THE FUTURE

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ST Sustainability Strategy

We conduct our business responsibly to create value for all stakeholders

WE LIVE OUR VALUES : People, Integrity, Excellence

WE PUT PEOPLE FIRST

- **Health & Safety**
- **Labor & Human Rights**
- **Development & Engagement**
- **Diversity & Inclusion**

WE IMPROVE EVERYBODY'S LIFE

- **Sustainable Profit**
- **Innovation**
- **Quality**
- **Sustainable Technology**

WE PROTECT THE ENVIRONMENT

- **Energy & Climate Change**
- **Water**
- **Waste & Effluents**
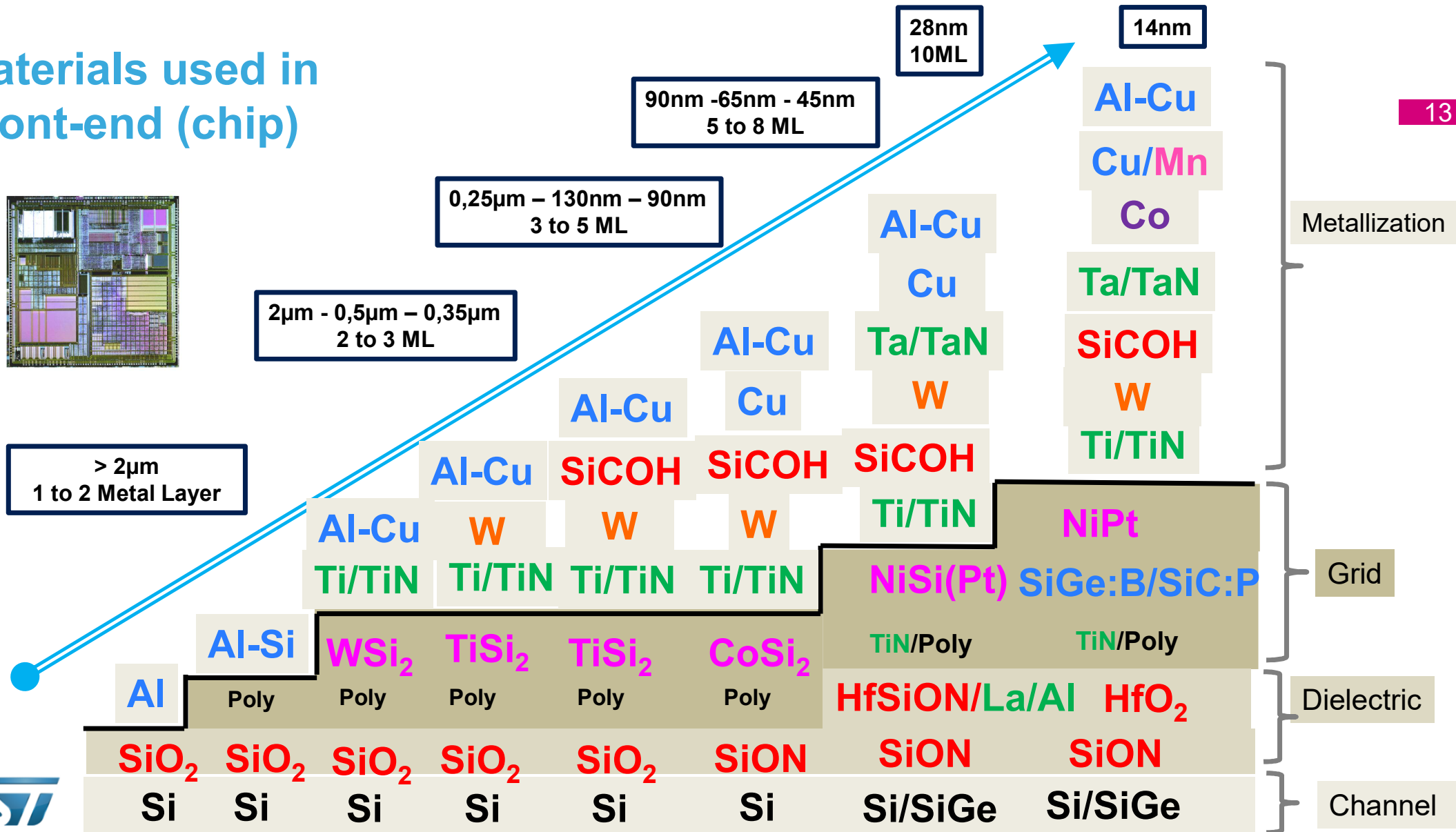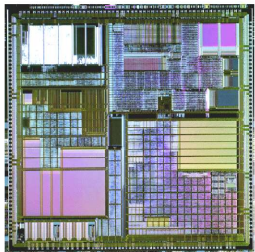- **Chemicals**

TOGETHER, WE SHAPE THE FUTURE

Supply Chain Responsibility, Education & Volunteering

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Materials in Semiconductor Industry

Materials used in Front-end (chip)

Box label
> 2µm 1 to 2 Metal Layer
2µm - 0,5µm – 0,35µm 2 to 3 ML
0,25µm – 130nm – 90nm 3 to 5 ML
90nm -65nm - 45nm 5 to 8 ML
28nm 10ML
14nm

	Al	Al-Cu	Al-Cu	Al-Cu	Al-Cu	Al-Cu	Al-Cu	Al-Cu	Category
Metallization						Cu	Cu	Cu/Mn	
							Ta/TaN	Co	
							W	Ta/TaN	
					SiCOH	SiCOH	SiCOH	SiCOH	
			W	W	W	Ti/TiN	W		
			Ti/TiN	Ti/TiN	Ti/TiN	Ti/TiN		Ti/TiN	
Grid		Al-Si	WSi₂	TiSi₂	TiSi₂	CoSi₂	NiSi(Pt)	NiPt	
			Poly	Poly	Poly	Poly	TiN/Poly	SiGe:B/SiC:P TiN/Poly	
Dielectric			HfSiON/La/Al	HfO₂					
	SiO₂	SiO₂	SiO₂	SiO₂	SiO₂	SiON	SiON	SiON	
Channel	Si	Si	Si	Si	Si	Si	Si/SiGe	Si/SiGe	

Metallization

Grid

Dielectric

Channel

FE & BE materials are concerned
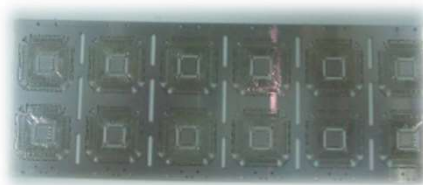
- ● Front-End:
  - VDP Targets
  - Tungsten Gases (WF6)
  - Special products (TBTDET*)

- ● Back-End:
  - Device Metals
  - Grid arrays
  - Wires
  - Lead frames
 - Ceram Opto. materials
  - Chemicals

Synthesis by Metal		
Metal	Material Segment	Material sub-segment
Gold	BE materials	CERAM OPTO
	BE materials	DEVICE METAL
	BE materials	GRID ARRAYS
	BE materials	LEADFRAMES
	FE materials	TARGETS VDP
	BE materials	WIRES
Tantalum	FE materials	CHEMICALS
	FE materials	TARGETS VDP
Tin	BE materials	BE CHEMICALS
	BE materials	DEVICE METAL
	BE materials	GRID ARRAYS
	BE materials	ORGANIC
	FE materials	TARGETS VDP
Tungsten	FE materials	GASES
	FE materials	TARGETS VDP

* Tert-Butylimido Tris(DiEthylamino) Tantalum

Critical materials

Dodd Franck Act in USA
EU CM Directive, 2010

3 TGs (Sn, Ta, W, Au) :
Traceability mandatory

- Be, Sb
- Brominated Flame Retardants
- Br Cl in composite materials
- PVC

Conflict minerals

Market Customers Restrictions

Responsible Minerals sourcing
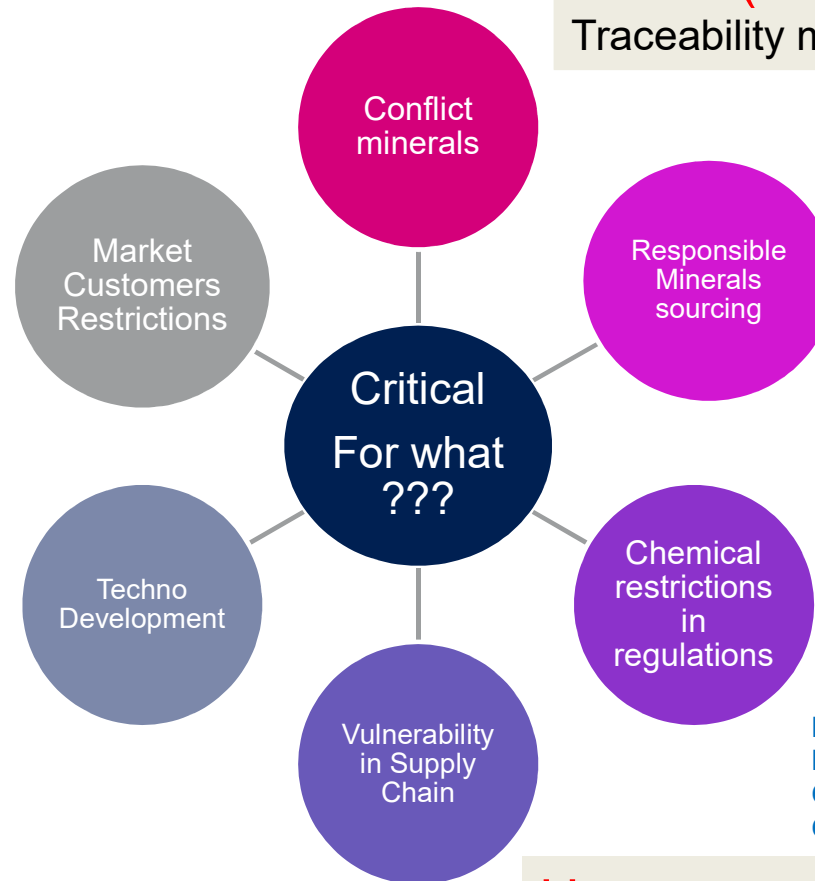
Co, Mica …
Ethic risk – small volume used vs batteries

Critical For what ???

Techno Development

Chemical restrictions in regulations

Pb, Cd, Cr, Hg, PFOS, PFOA, PBB, PBDE, Phthalates
Usage highly controled

- In, Hf, Ge, Ga,
- InP, InGaAs, PZT, GeSn

Vulnerability in Supply Chain

Reach SVHCs
RoHS, WEEE
California 65
China RoHS

He, Pt, Pd
Recent crisis on He (2012, 13, 17), alert 2019/20
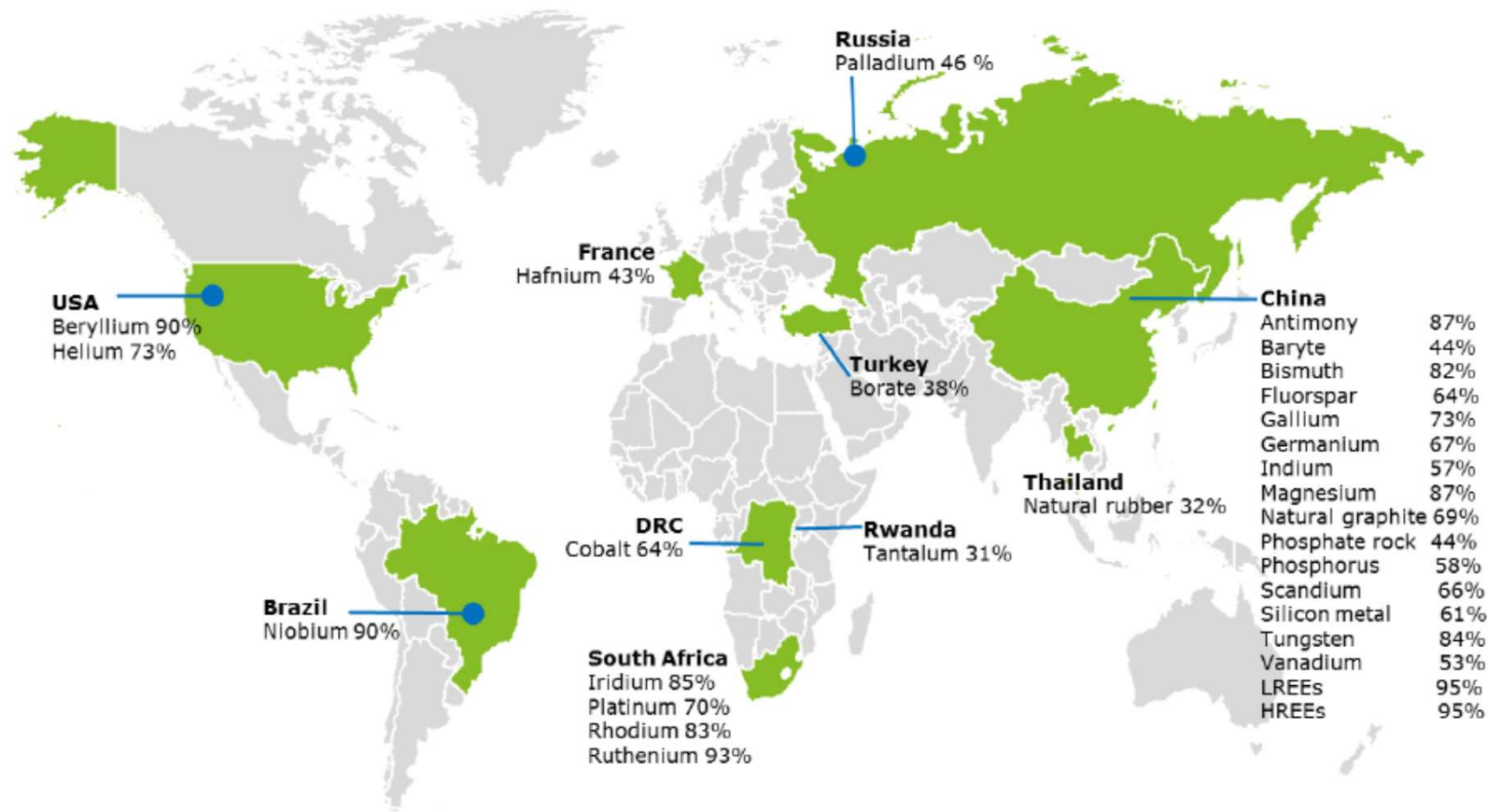
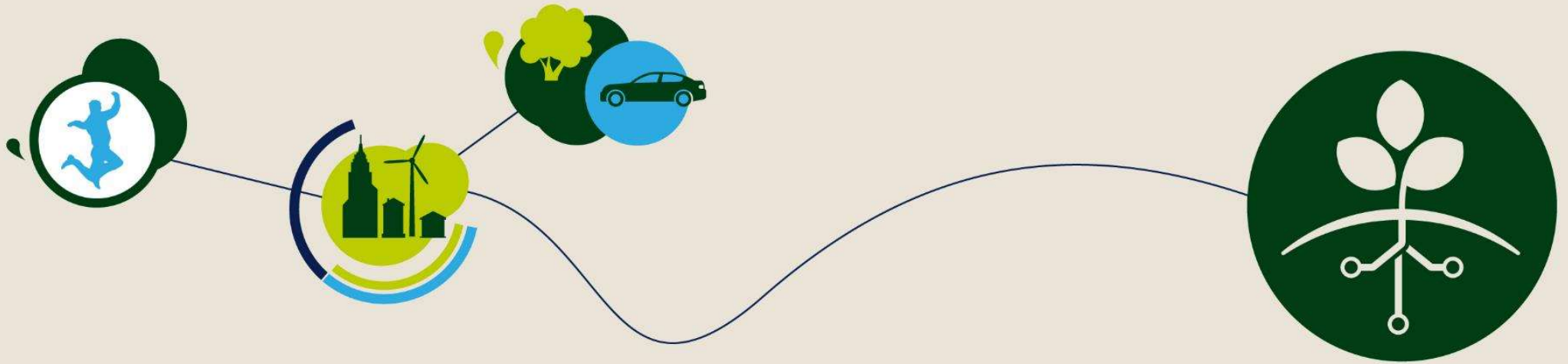# Criticality assessment of raw materials for EU

Elements (Selection)	Main WW producers (average 2010-2014)	Dependency rate to importation	Recycling rate for End of Life materials	Usage in Micro-elec. ?	Critical for Micro –nano elec.
W	China (84%); Russia (4%)	44%	42%	Yes – Front End CVD & ALD (WF6; Targets)	Conflict Minerals
Pt	South Africa(83%)	99.6%	14%	Yes	
Hf	France (43%); US (41%); Ukraine (8%); Russia (8%)	9%	1%	Yes - Front End (ALD : HfCL4)	
Co	DRC (64%); China (5%); Canada (5%)	32%	0%	Yes	Responsible sourcing program
Ga	China (85%; Germany (7%) Kazakhstan (5%)	34%	0%	Yes – As Ga (RF; IOT); GaN/Si devices	
In	China (57%); South Korea (15%); Japan, (10%)	0%	0%	Yes (Materials III/V InP, InGaAs)	
Ta	Rwanda (31%) – DRC (19%); Brazil (14%)	100%	1%	Yes – FE Targets	Conflict Minerals
He	US (73%); Qatar (12%); Algeria (10%)	96%	1%	Yes FE fabs	Supply critical issue
Ge	China (67%); Finland (11%); Canada (9%); US (9%)	64%	2%	Yes – Tech node 7nm	

- 27 elements / Raw Materials are evaluated as Critical by EU (2017)
- Nota : assessed as non critical : Ti, Cu, Li, Au, Ni, Al, Sn, Se, Te, Si

Main contributor countries supplying critical materials

Russia
Palladium 46 %

France
Hafnium 43%

USA
Beryllium 90%
Helium 73%

Turkey
Borate 38%

China
Antimony	87%
Baryte	44%
Bismuth	82%
Fluorspar	64%
Gallium	73%
Germanium	67%
Indium	57%
Magnesium	87%
Natural graphite	69%
Phosphate rock	44%
Phosphorus	58%
Scandium	66%
Silicon metal	61%
Tungsten	84%
Vanadium	53%
LREEs	95%
HREEs	95%

Thailand
Natural rubber 32%

DRC
Cobalt 64%

Rwanda
Tantalum 31%

Brazil
Niobium 90%

South Africa
Iridium 85%
Platinum 70%
Rhodium 83%
Ruthenium 93%

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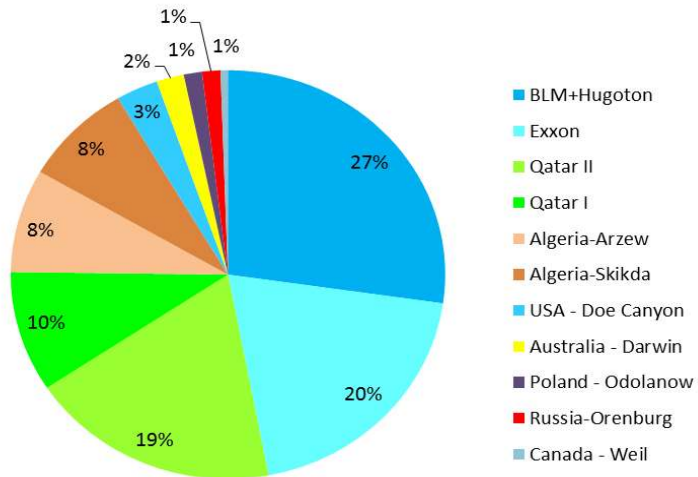# Helium a critical gas for Semi.

Helium supply risk

- Helium is a rare molecule used in MRI [*], military & aerospace, optic fiber, lab (ie CERN), and Semiconductor industry

- Helium is coming from Natural Gas, so dependent on worldwide economy (energy consumption)

- Helium cannot be stored massively and long term (except underground)

- Offer & Demand are almost balanced since years, with demand increasing ~3.0%/Y, and offer declining until 2021 (BLM effect)

- BLM [**] used to be the unique underground storage, with massive reserve, but supply is ramping down and closing in 2021

- Qatar supply (~30% of WW offer), is at risk since June 2017, due to diplomatic issue btw Qatar & Saudi Arabia

- The last two worldwide crisis (2012-2013 & 2017), put the entire world close to shortage

**It is strategic to reduce risk of supply discontinuation,
because a structural shortage is predicted in 2019-2021**

[*] Magnetic Resonance Imaging   [**] Bureau of Land Management, from USD Gvt

Helium sources capacities 2017
(estim. 7340 mmscf)

- BLM+Hugoton
- Exxon
- Qatar II
- Qatar I
- Algeria-Arzew
- Algeria-Skikda
- USA - Doe Canyon
- Australia - Darwin
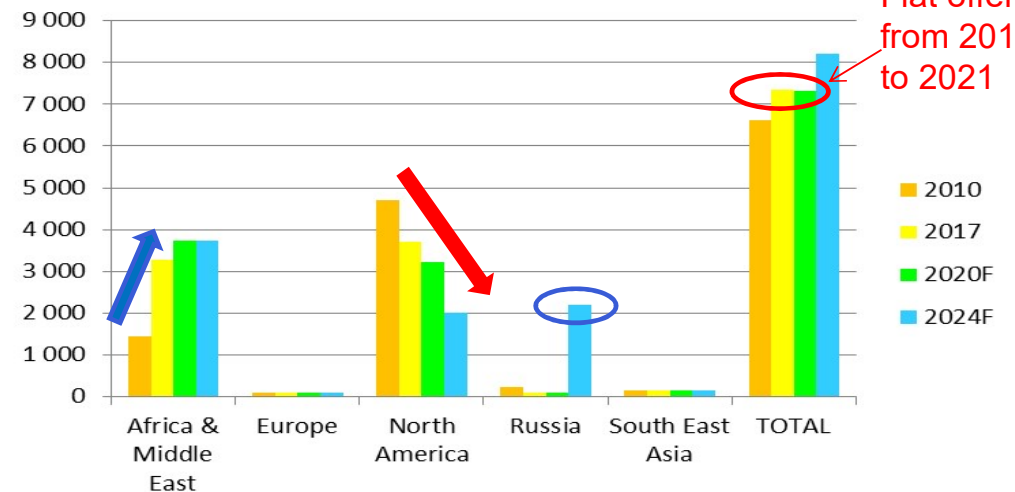- Poland - Odolanow
- Russia-Orenburg
- Canada - Weil

In 2017…

✓ USA remains leader on the market, with 50% of the market

✓ Africa & Middle East represents 45%, out of which Qatar ~30%
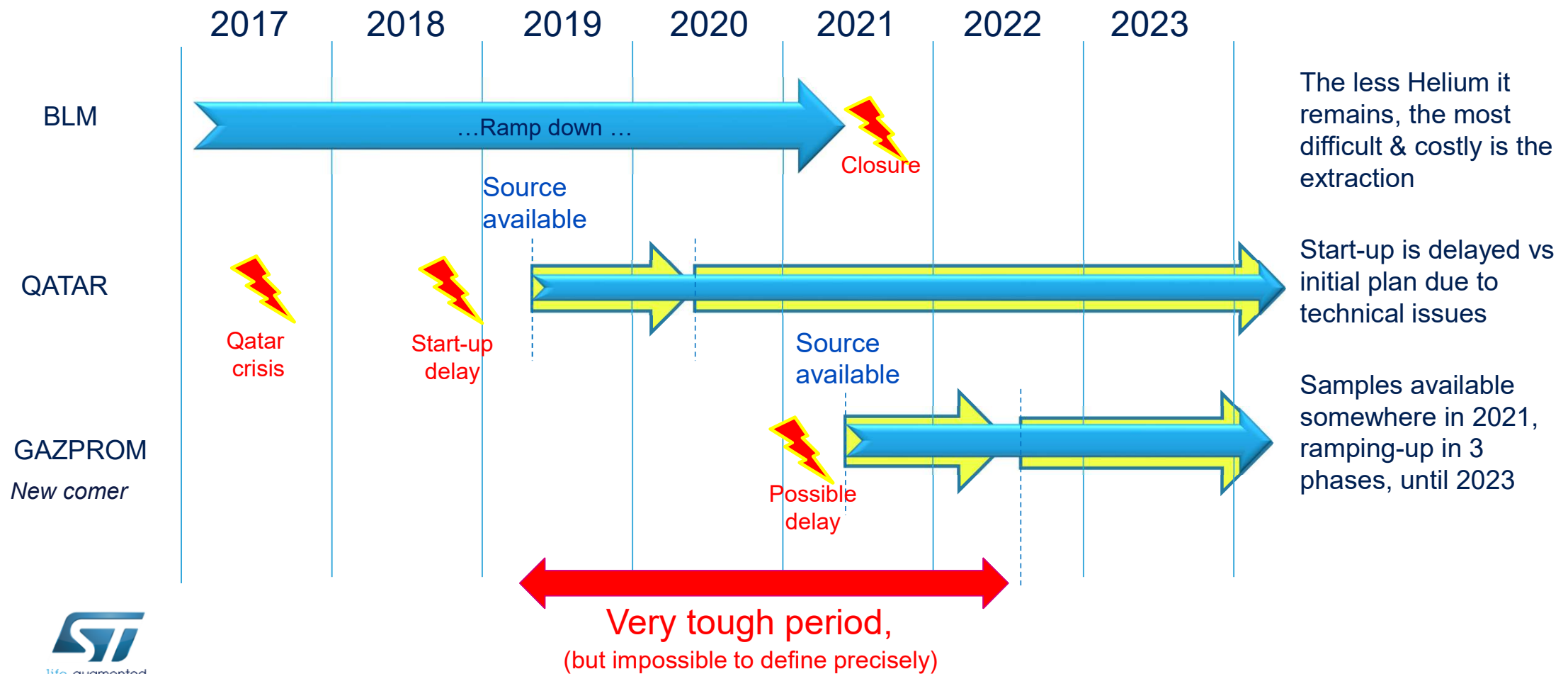
In the future …

➢ Qatar will become the source #1

➢ US will decline to #3 when BLM will close

➢ Siberian source will bring Russia #2

Helium sources capacity trend

Flat offer from 2017 to 2021

Legend: 2010, 2017, 2020F, 2024F

Categories: Africa & Middle East, Europe, North America, Russia, South East Asia, TOTAL
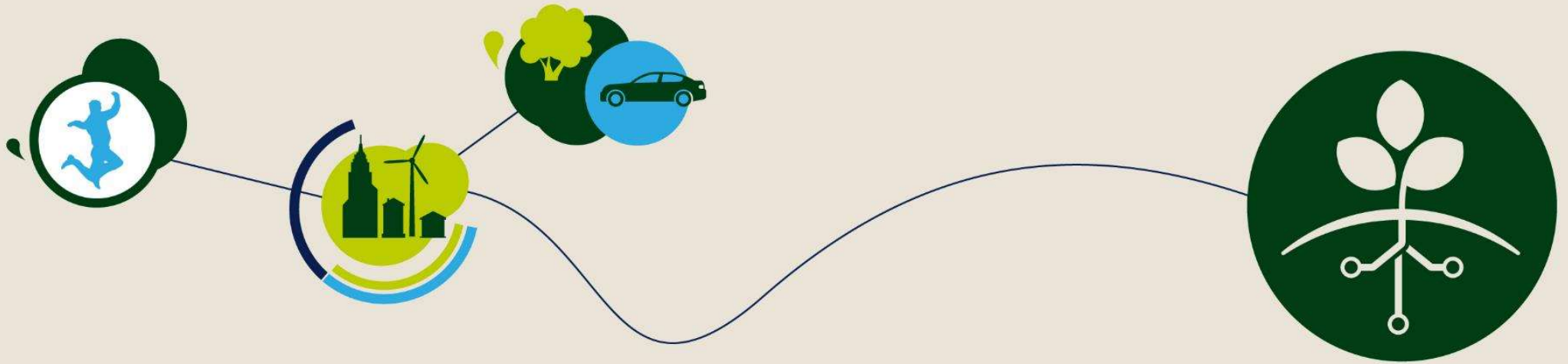
Semiconductor weight inside Helium market…

- Biggest size of Semiconductors manufacturing plant is 20 ISO/yr.

- Medium size MRI [**] manufacturing plant is 20 ISO/yr.

- Biggest size MRI manufacturing plant is 50 ISO/yr.

- ESA (Arianespace) in Guyane is 50 ISO/yr.

- Worldwide Helium market is + 7.000 ISO/yr.

=> **Semiconductor market is very demanding in purity, but relatively small in market share (<20%)**

[*] ISO is a large insulated container of liquid helium, containing 26.480 m3 of helium (usable charge)
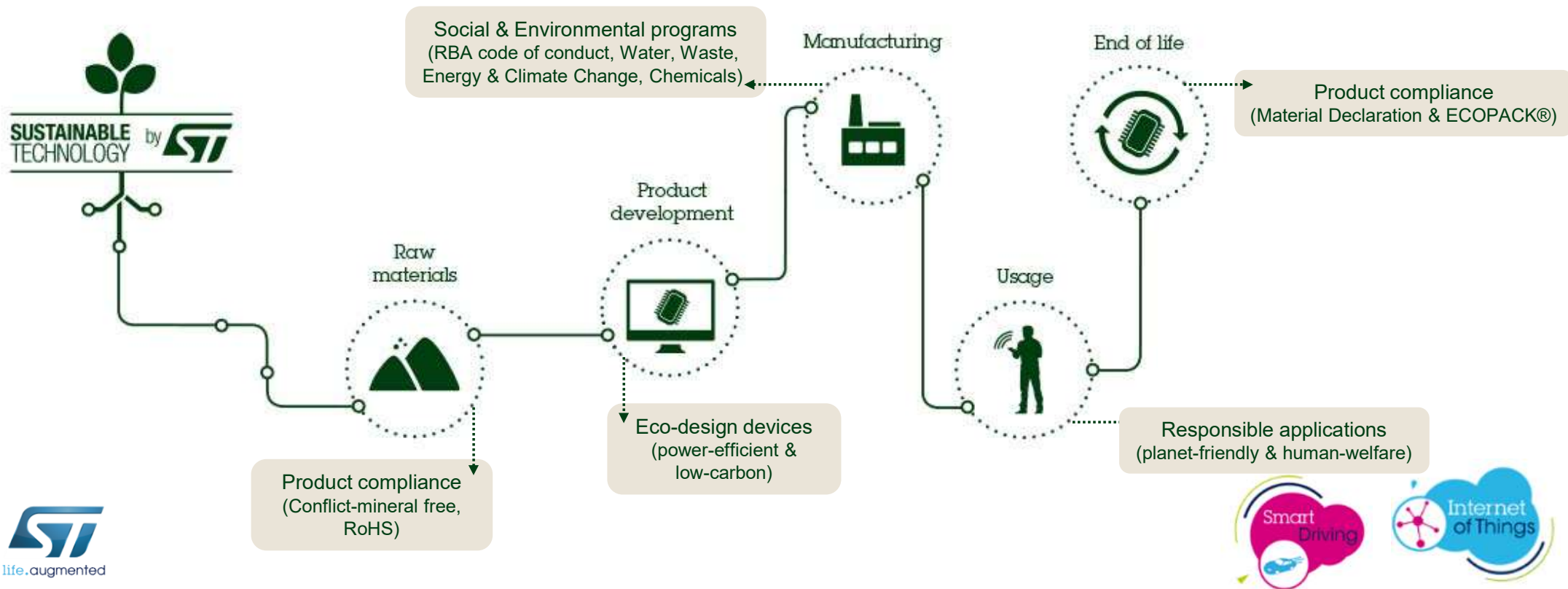
[**] Magnetic Resonance Imaging

Product Stewardship

Our Sustainable Technology program aims to develop responsible products which
- improve our social and environmental footprint at every stage of the product life
- have the greatest positive impact on the planet and people in the end-application

Social & Environmental programs
(RBA code of conduct, Water, Waste,
Energy & Climate Change, Chemicals)

Manufacturing

End of life

Product compliance
(Material Declaration & ECOPACK®)

Raw
materials

Product
development

Usage

Eco-design devices
(power-efficient &
low-carbon)

Responsible applications
(planet-friendly & human-welfare)

Product compliance
(Conflict-mineral free,
RoHS)

Our approach ...

- Product Compliance
  - Compliance with legislation and with customers' requirements

- Eco-Design
  - Eco-design assess the environmental impacts of products during design phase to minimize it

- Responsible Applications
  - Identify products that augments Responsible applications

- Label for Responsible products
  - Identify products that provide clear environmental and social benefits to society

Regulation

Proactivity

Label

- Material Declaration
- ECOPACK® (RoHS)
- Conflict Minerals free

- Low-carbon product
- Power-efficient product
- Planet-friendly application
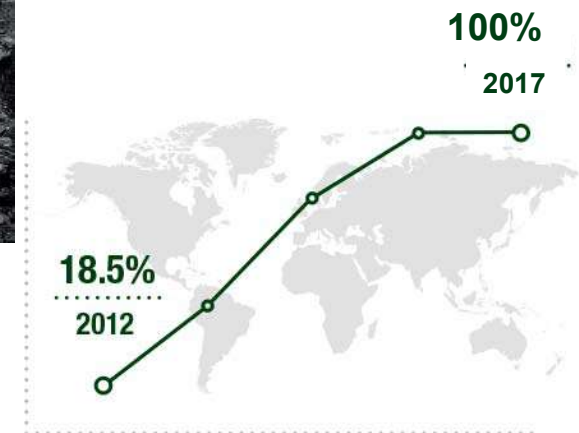- Human-welfare application

Social compliance: free of Conflict Minerals

- We require our upstream supply chain to identify the origin of the 3TG (**T**antalum, **T**in, **T**ungsten and **G**old) metals we are using in our manufacturing.

- This is to comply to the US Dodd Frank July 2010 legislation. It requires companies operating in the US to demonstrate that their products do not contain 3TG that are sourced from mines operated by armed groups in conflict zones (mostly in Democratic Republic of Congo).
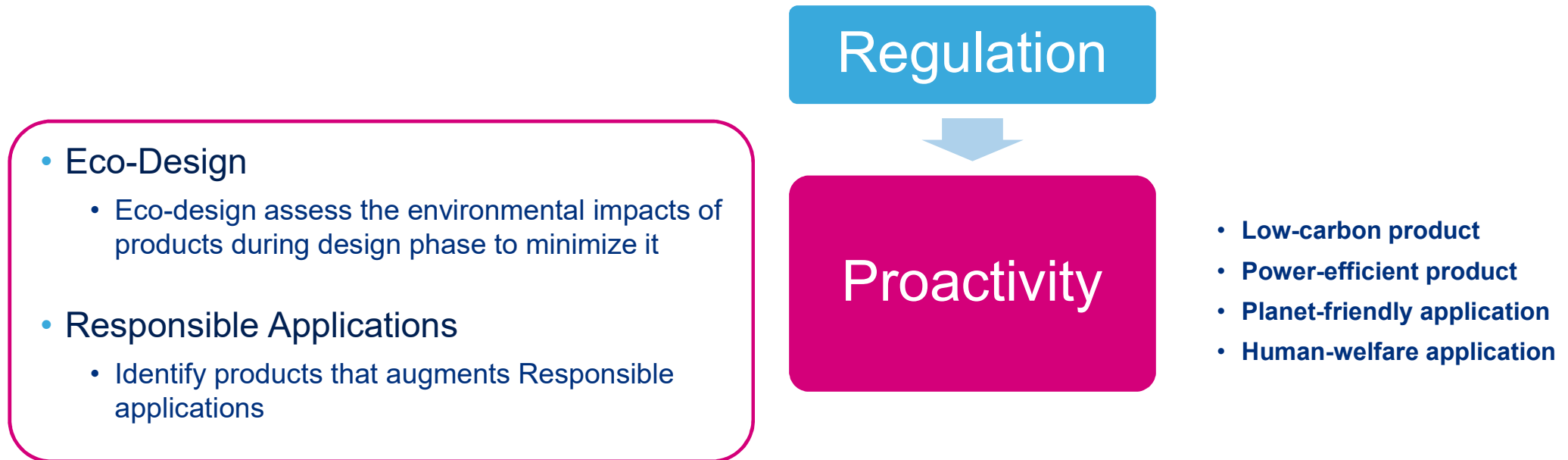

100%
2017

18.5%
2012

- Percentage of ST products which are conflict free

How to reduce our impact ?

Regulation

→

Proactivity

- **Low-carbon product**
- **Power-efficient product**
- **Planet-friendly application**
- **Human-welfare application**

- Eco-Design
  - Eco-design assess the environmental impacts of products during design phase to minimize it

- Responsible Applications
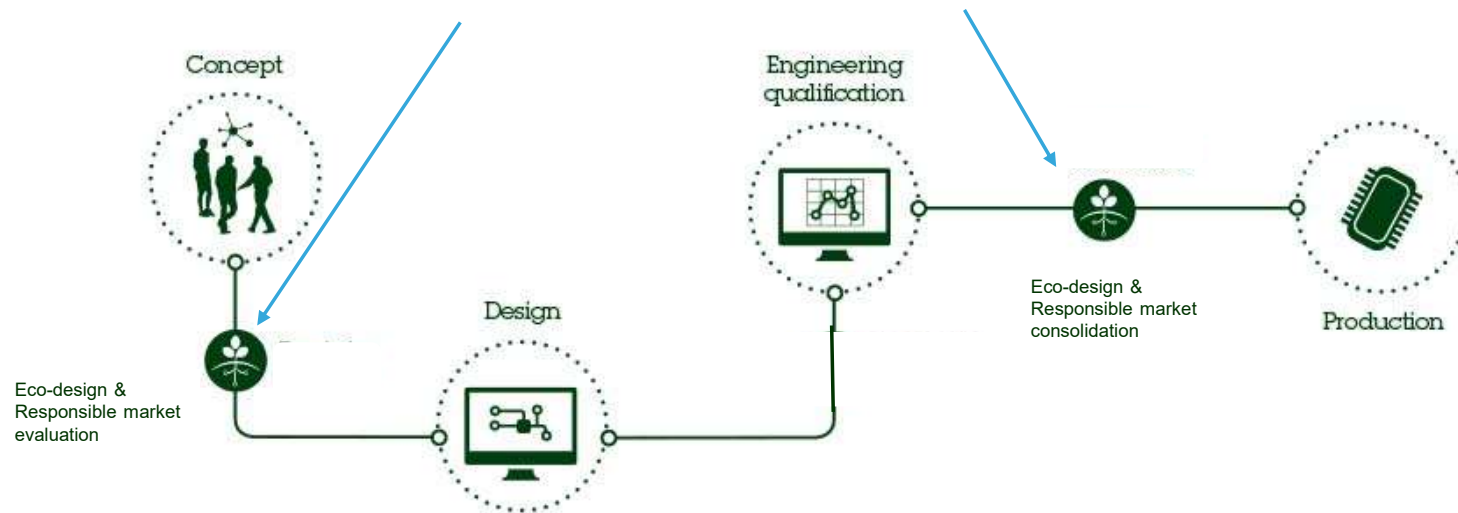 - Identify products that augments Responsible applications

Overview of the process

- Sustainable Technology program is part of **Product Development Process** (PDP)

- Eco-design process is applied:

  - At early stage of the design before "**New Product Request**" (before design phase)

  - Consolidated at "**Product Qualification Certificate**" (before mass production phase)

Concept

Design

Engineering qualification

Eco-design & Responsible market evaluation

Eco-design & Responsible market consolidation

Production

Eco-design assessment

- For every new project, R&D teams have to assess few key parameters to evaluate the future impact of the product.

- It helps to identify:
  - Power-efficient products (consuming less electricity)
  - Low-carbon products (reducing the manufacturing footprint)

- Eco-design assessment aims to increase consciousness of project teams on their contributions (depending of their choices) on the final product impact.

Power-efficient product

Low-carbon product

Product eco-design assessment

Compare vs predecessor or competitor:

Does ST chip demonstrate power efficiency in one of the following areas?
- Efficiency in power consumption of ST chip
- Efficiency in power loss of ST chip
- Efficiency in power dissipation/consumption of the total electronic system the ST chip is included

Compare vs predecessor or competitor:

- Reduction in number of metal layers?
- Reduction in number of masks?
- Reduction of die size?
- Reduction of interconnect size?
- Reduction of package size?
- Integration of features?
- Increase of wafer size?
- Reduction of wafer thickness?
- Substitution of gold or lead?
- Reduction of interconnect size?
- Increase of ECOPACK grade?
- Increase of product lifetime?
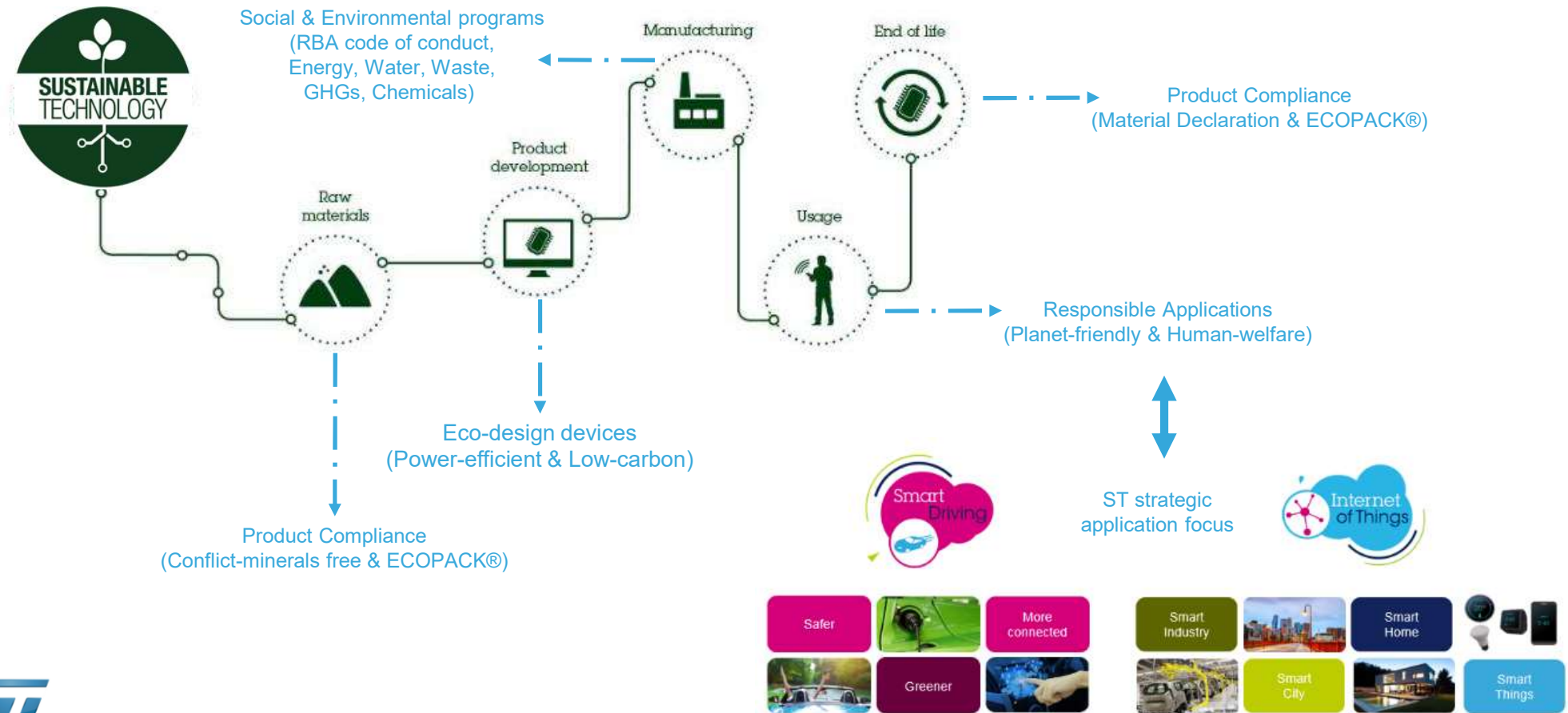- Other optimization?

- We declare responsible products, in Environmental or Social domain, as soon as a product is demonstrating eco-design achievements or enabling a responsible application.

Environmental responsible products

Social responsible products

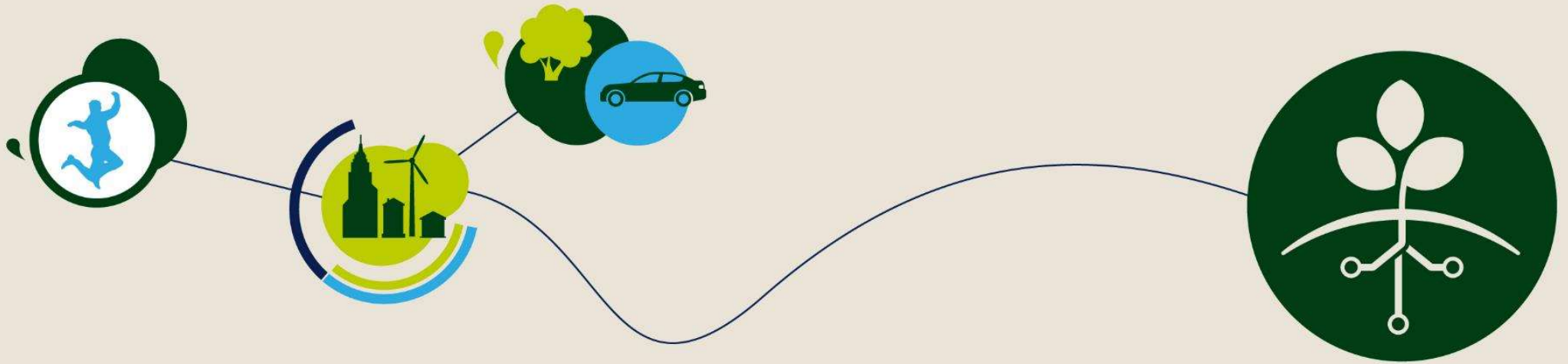| Power-efficient product | Low-carbon product | Planet-care application | Human-welfare application |

- Every year we report externally to investors and rating agencies ST revenues generated by Responsible products.

  - 2025 goal is to reach 30% of revenues from responsible products

Program covers the life cycle of ST products

SUSTAINABLE TECHNOLOGY

Social & Environmental programs
(RBA code of conduct,
Energy, Water, Waste,
GHGs, Chemicals)

Manufacturing

End of life

Product
development

Raw
materials

Usage

Product Compliance
(Material Declaration & ECOPACK®)

Responsible Applications
(Planet-friendly & Human-welfare)

Eco-design devices
(Power-efficient & Low-carbon)

Product Compliance
(Conflict-minerals free & ECOPACK®)

Smart Driving

ST strategic
application focus

Internet of Things

Safer

More connected

Greener

Smart Industry

Smart City

Smart Home

Smart Things

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Questions ?