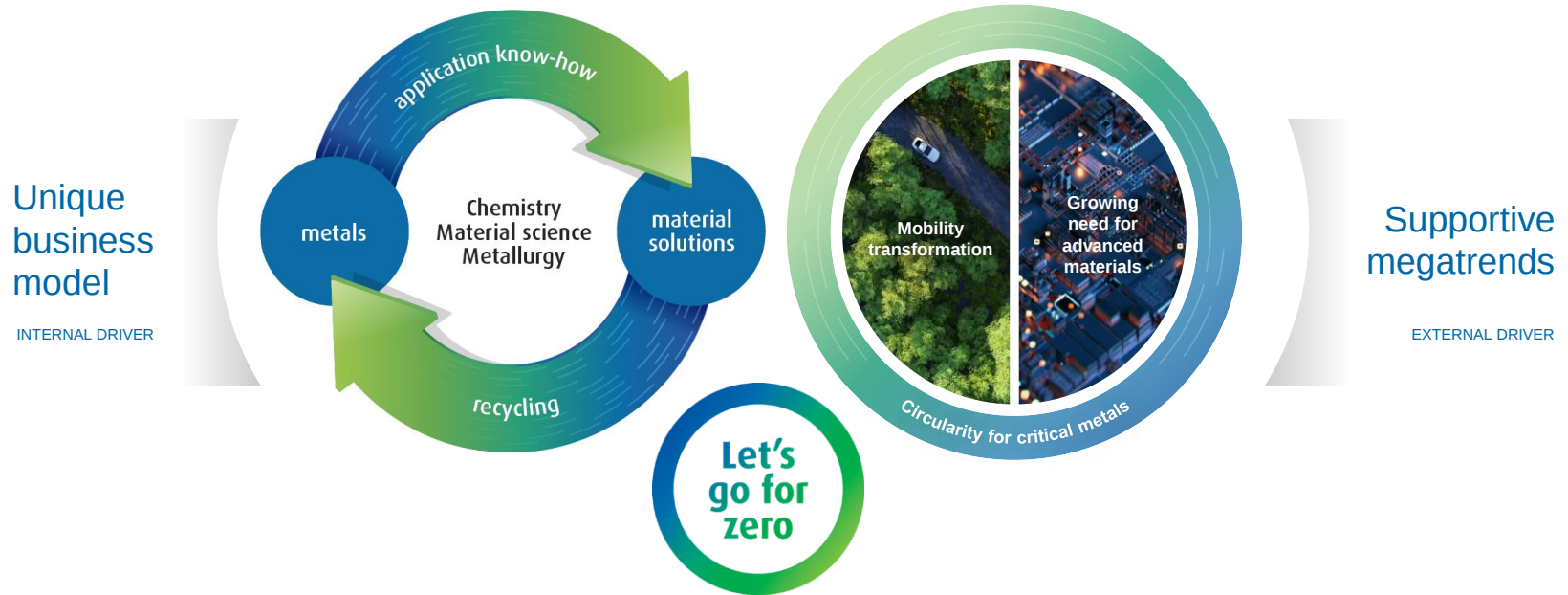


Resilient supply of Ge substrates for US space market



Kristof Dessein
Innovation Director
Umicore – Electro-Optic Materials

Umicore – A global materials technology company



Industry **leader** in sustainability

Umicore – A global materials technology company



Umicore Electro-Optic Materials focuses on germanium products and infra-red optics

51 SB Antimony	33 AS Arsenic	83 BI Bismuth	3 LI Lithium
27 CO Cobalt	29 CU Copper	31 GA Gallium	32 GE Germanium
25 MN Manganese	28 NI Nickel	48 PD Palladium	78 PT Platinum
74 W Tungsten	59 PR Praseodymium	45 RH Rhodium	44 RU Ruthenium
73 TA Tantalum			

17 out of 34 **critical raw materials** part of Umicore's portfolio

Umicore's position in the Ge value chain



Decades of experience in germanium refining & recycling



Largest germanium producer & recycler outside of China

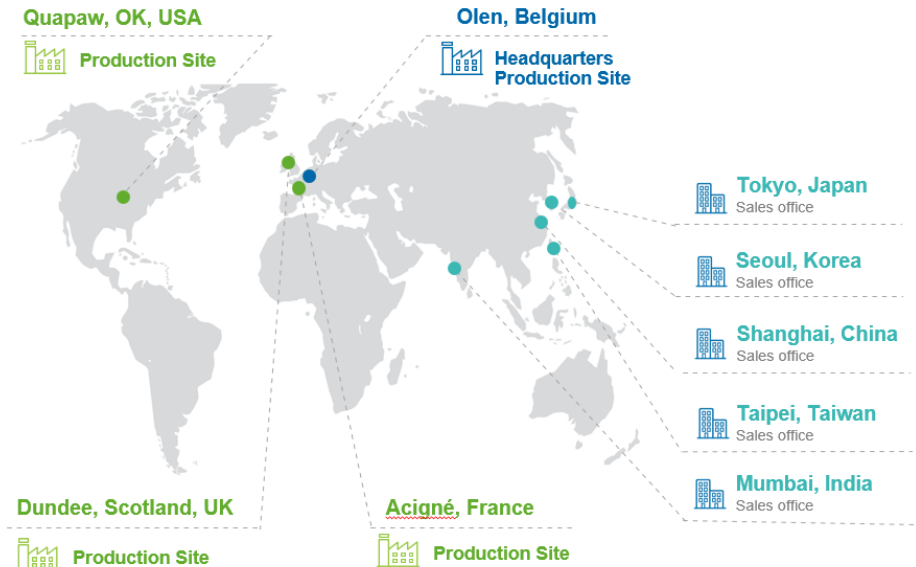


Extensive customer base in Europe and US

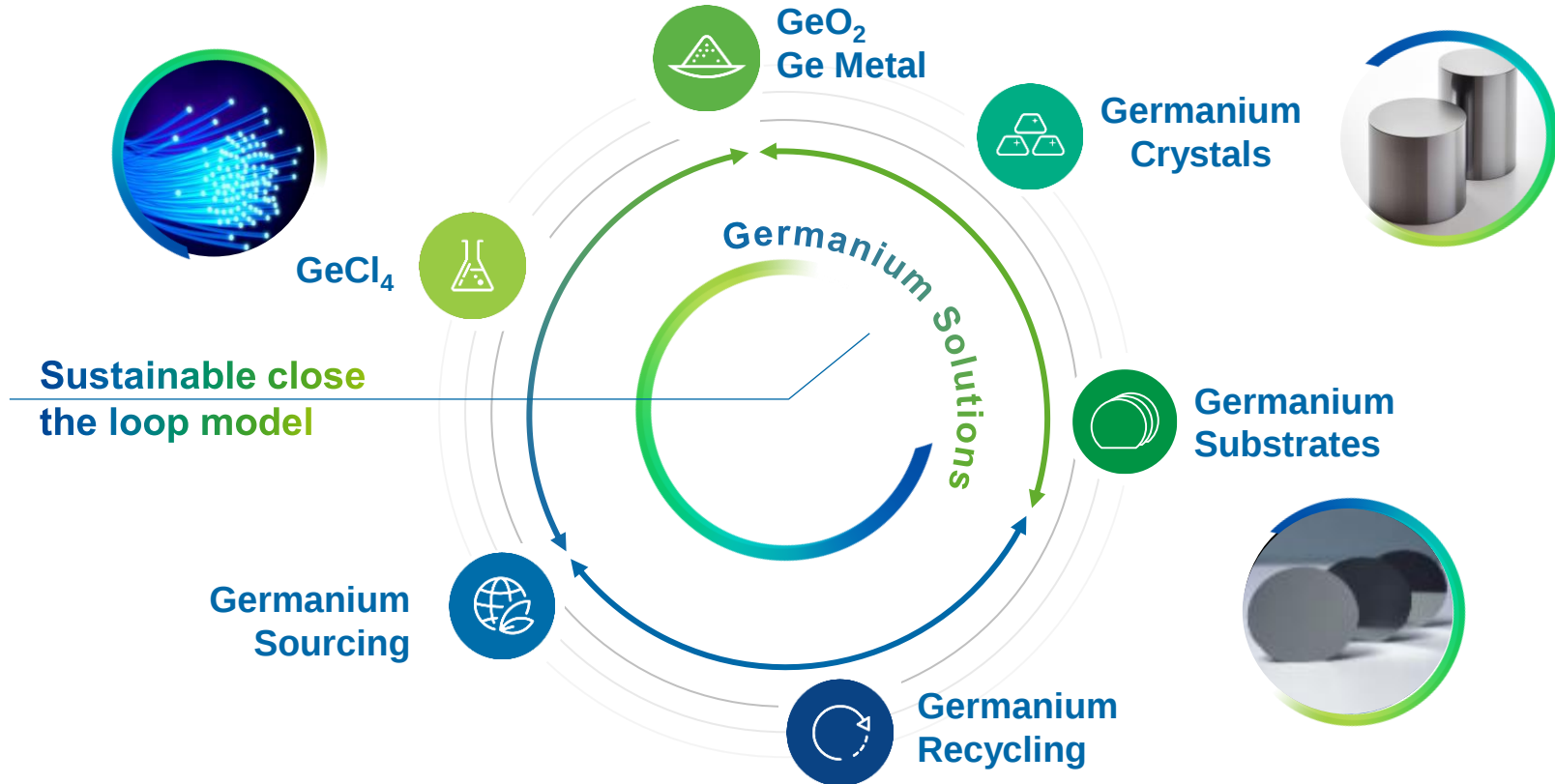


Recognised as one of the most sustainable companies in the world

Geographic presence Umicore's Ge operations



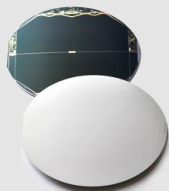
Umicore's Germanium Flow Sheet



Serving strategic applications today and tomorrow

Today

**Germanium
Substrates**



**Space
solar
cells**



Tomorrow

**Photonics
Non-space solar
Space exploration
Constellations**



**Germanium
Tetrachloride**



**Optical
Fiber
Cable**



**Precursor for
microelectronics**



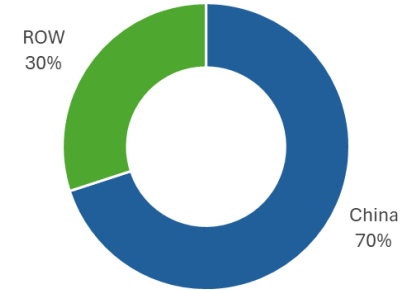
Global Germanium Value Chain

- Small minor metals market (130-150 tons/yr) with 70% of total primary output from China
- Export control measures introduced August '23 by China in view of geo-political tensions
- Export licenses exclude US companies and military end use
- Umicore has ensured continued supply for its customer base since the introduction of the export control

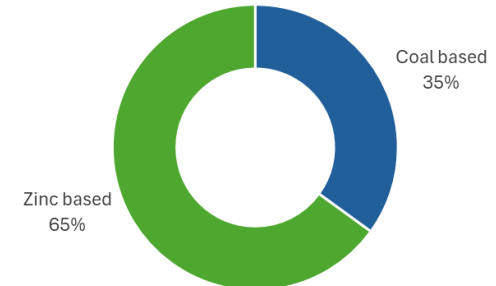


Creating a resilient supply base has been part of
Umicore's strategy for two decades

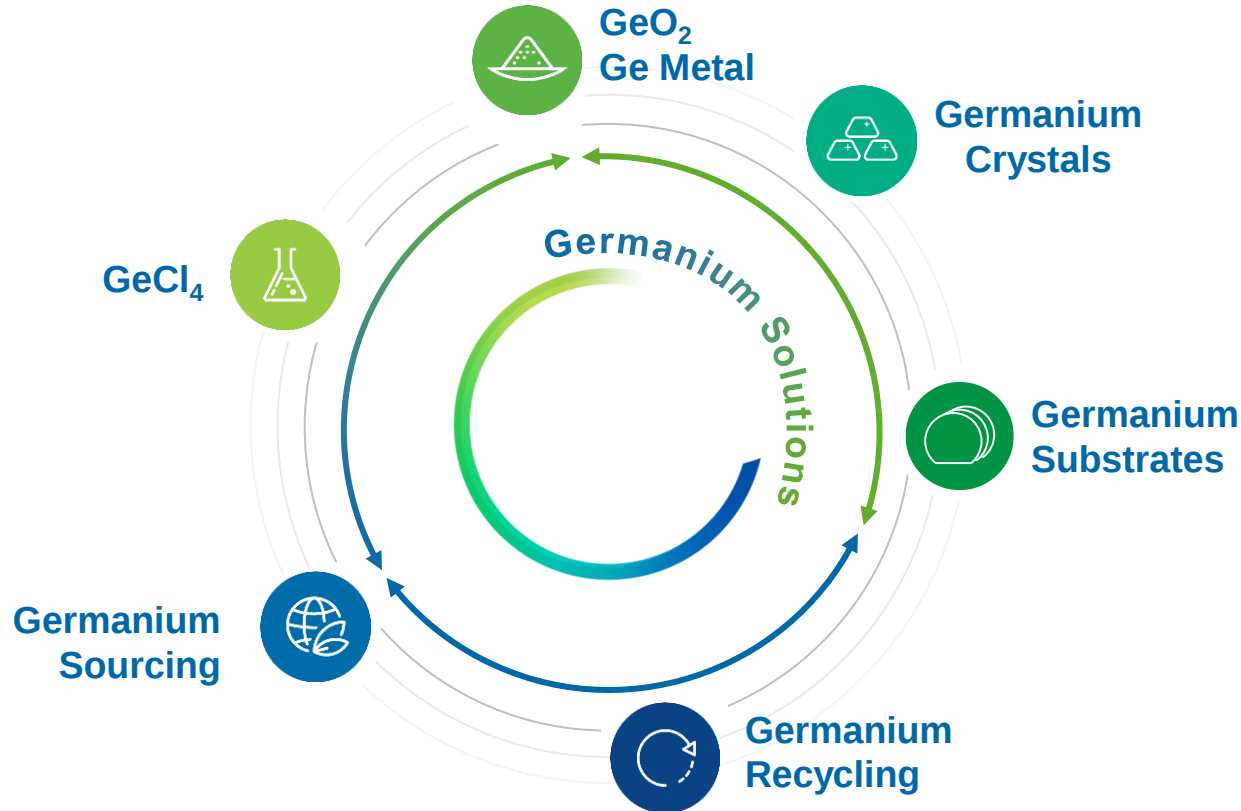
*Origin of global primary
germanium supply*



*Type of global primary
germanium supply*



Umicore's strategy in creating a resilient supply



Umicore's strategy in creating a resilient supply



**Upstream
Development**

Recycling

Innovation

Upstream Development

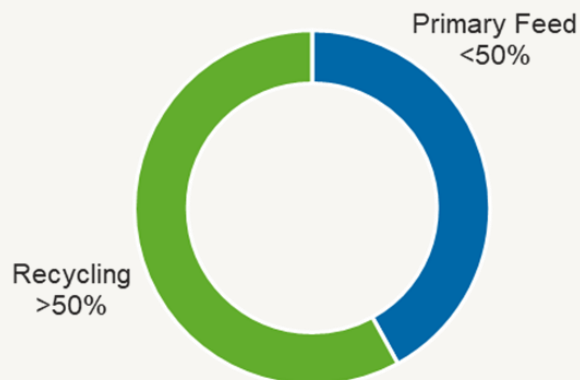
Umicore's Ge sourcing portfolio



Germanium
Sourcing



Primary vs secondary sourcing



Umicore: 100% Sustainable
Germanium supply



Umicore is the only Germanium
producer with 100% sustainable
germanium,

and can additionally offer 100%
recycled germanium

100% Sustainable Germanium
GUARANTEED

100% Recycled Germanium
AVAILABLE *

* Limited availability

Upstream Development

Germanium
Sourcing



Long term deal with STL in DRC

- Umicore has been recovering Ge from Big Hill indirectly for 20 years
- Last year, a new partnership has been signed to further support extraction of Ge from these old Zn tailings



Your partner in Ge recycling

Continuous research to enlarge portfolio



Germanium
Recycling



HIGH CAPACITY

Several thousands of tons of recycling streams annually



EXTENSIVE CAPABILITIES

Pyro and hydro metallurgy for complex streams



EFFICIENT PROCESSES

Germanium can be recovered from streams with Ge content of 0.5 % for solids and 0.5 g/l for liquids

We partner with customers to recover Ge directly from their waste streams

Innovation: Re-usable Ge substrate



Germanium
Substrates

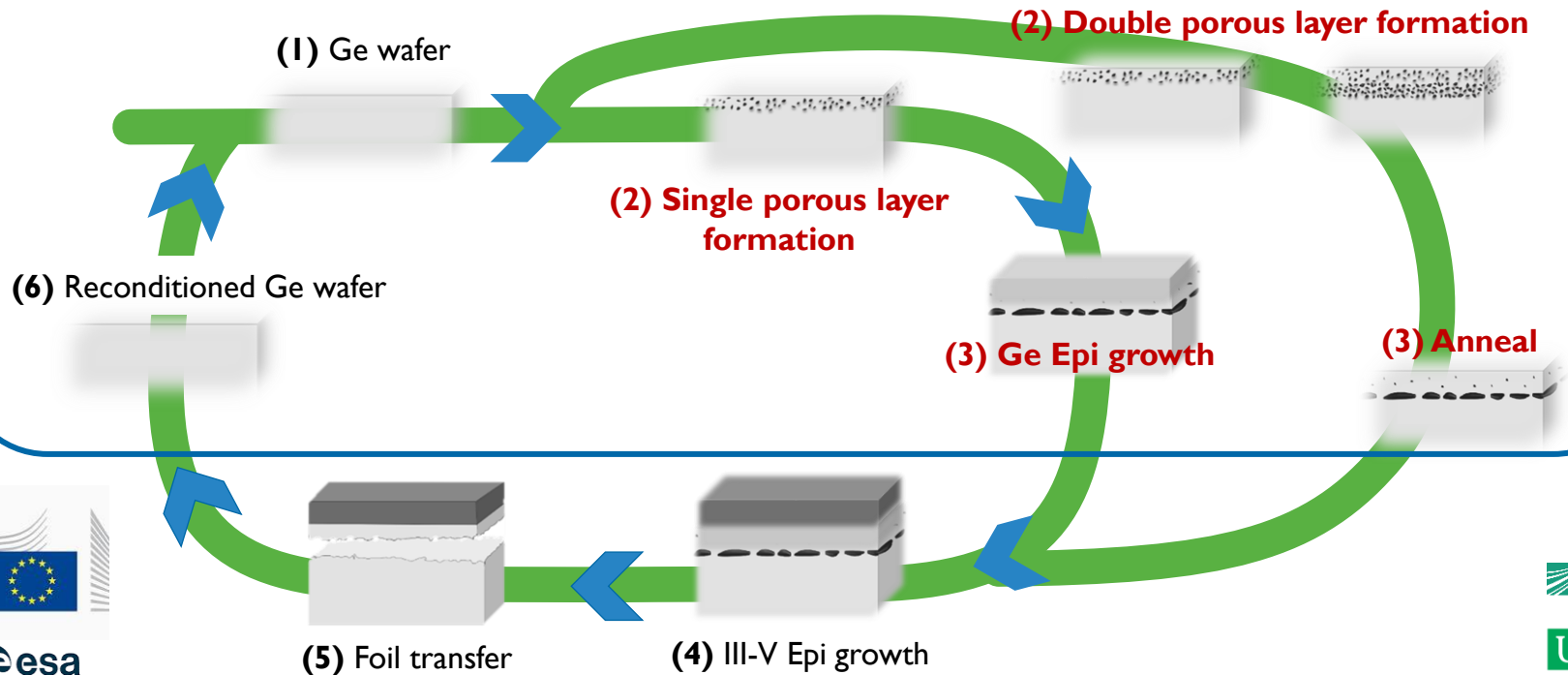
- growth template ($< 1\mu\text{m}$)
- bottom cell ($< 10\mu\text{m}$)
- radiation shielding ($> 20\mu\text{m}$)
- mechanical support ($> 200\mu\text{m}$)

GOING FOR...
LIGHTER
FLEXIBLE
COST EFFECTIVE
GE SUBSTRATES



Innovation: Re-usable Ge substrate

Two routes being explored in parallel

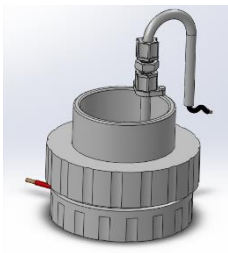




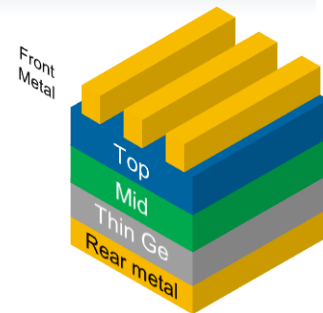
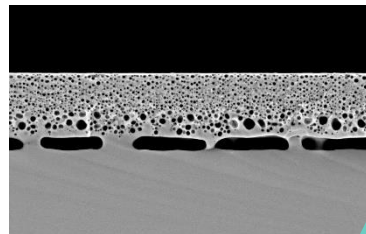
Re-usable Ge substrate: towards pilot scale

Germanium
Substrates

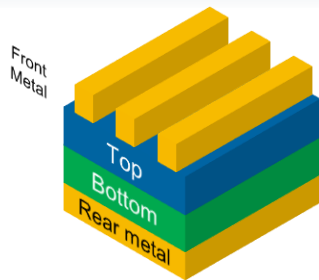
Proof-of-concept & Scalable Process Dvt



Flexible blanket demonstration



2J Flexible Solar Cell Demonstration



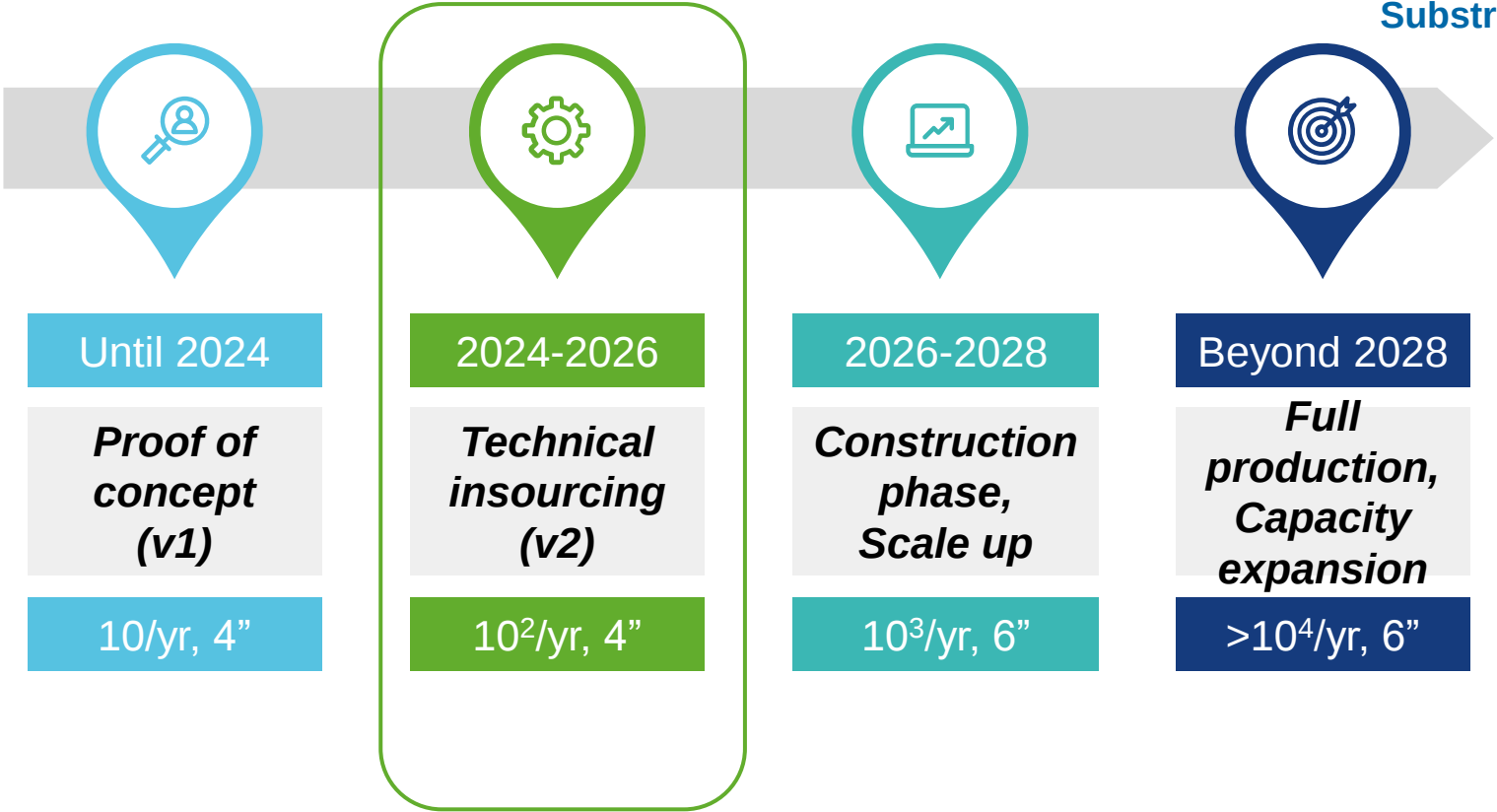
Flexible Solar Array



Germanium
Substrates

Re-usable Ge substrate project – way forward

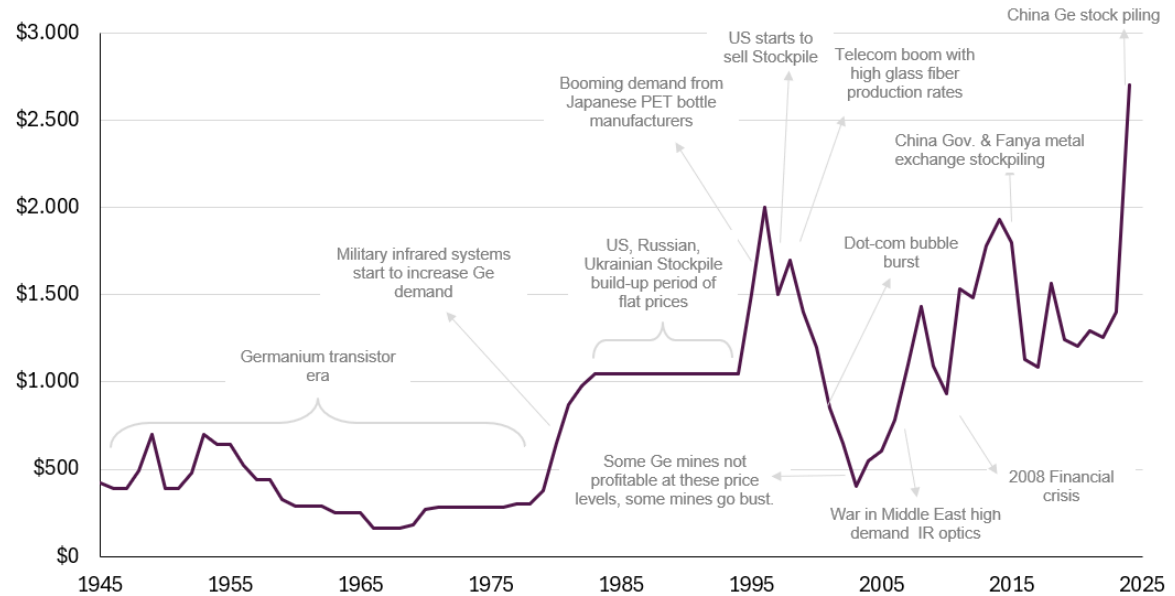
Upscaling to 6" and pilot fab @ Umicore Belgium



Strategic stock

- Umicore holds strategic stock in various forms
- Umicore manages customer stocks via tolling schemes

Historical Germanium reference pricing (USD/Kg)



Conclusion



Diversification is key towards a more resilient Ge supply chain