

Building resilient semiconductor supply chains

Dr Andy G Sellars
Advanced Materials Show
30 June 2022



Timeline

National semiconductor strategy
Consultations with 200 companies, 50 universities

Technology Strategy Board
Driving Innovation
**Compound Semiconductors:
market analysis and UK capability**

Myrddin Jones, Lead Technologist
Paul Mason, Head of Development
Steph Morris, Lead Specialist
Andy Sellars, Lead Technologist
19th August 2014



innovate UK
**Compound Semiconductor Consultation Workshop
Birmingham, 2nd June 2015**

Andy Sellars, Lead Technologist, High Value Manufacturing
andy.sellars@innovateuk.gov.uk
@hi_tech_uk



Business case to
HM Treasury

Compound Semiconductor
Applications Catapult
Technology Scotland, 4th May 2016

Andy Sellars, MBA, PhD, MSc
Lead Technologist, Manufacturing & Materials
andy.sellars@innovateuk.gov.uk
@andy_g_sellars

Innovate UK

Chancellor's
announcement



Property search



2013

2014

2015

2016

2017

Prime Minister's roundtable
on electric vehicles



State of the art facilities

Opened mid-2019



Official opening
Royal Society



International partnership
with ITRI, Taiwan



Driving Electric Revolution
Industrialisation Centre



2018

2019

2020

2021

2022

CATAPULT

fostering innovation



Government consultation

UK Parliament

Committees

[UK Parliament](#) > [Business](#) > [Committees](#) > [Business, Energy and Industrial Strategy Committee](#) > The Semiconductor Industry in the UK

The Semiconductor Industry in the UK

Inquiry

This inquiry will examine the strengths and weaknesses of the semiconductor industry and its supply chain in the UK.

Semiconductor materials are essential in electronics and are used in computer chips in everything from fridge freezers to airliners. The new inquiry comes amidst an ongoing global shortage of semiconductors that has caused widespread disruption to supply chains. This has impacted the production of popular products like the [Mini](#) and the [PlayStation 5](#).

In this inquiry the committee seeks to understand current and future demand for computer chips in the UK, the strengths and weaknesses of the UK semiconductor industry and its supply chain, and opportunities for collaboration between the United States, the European Union and other allies.

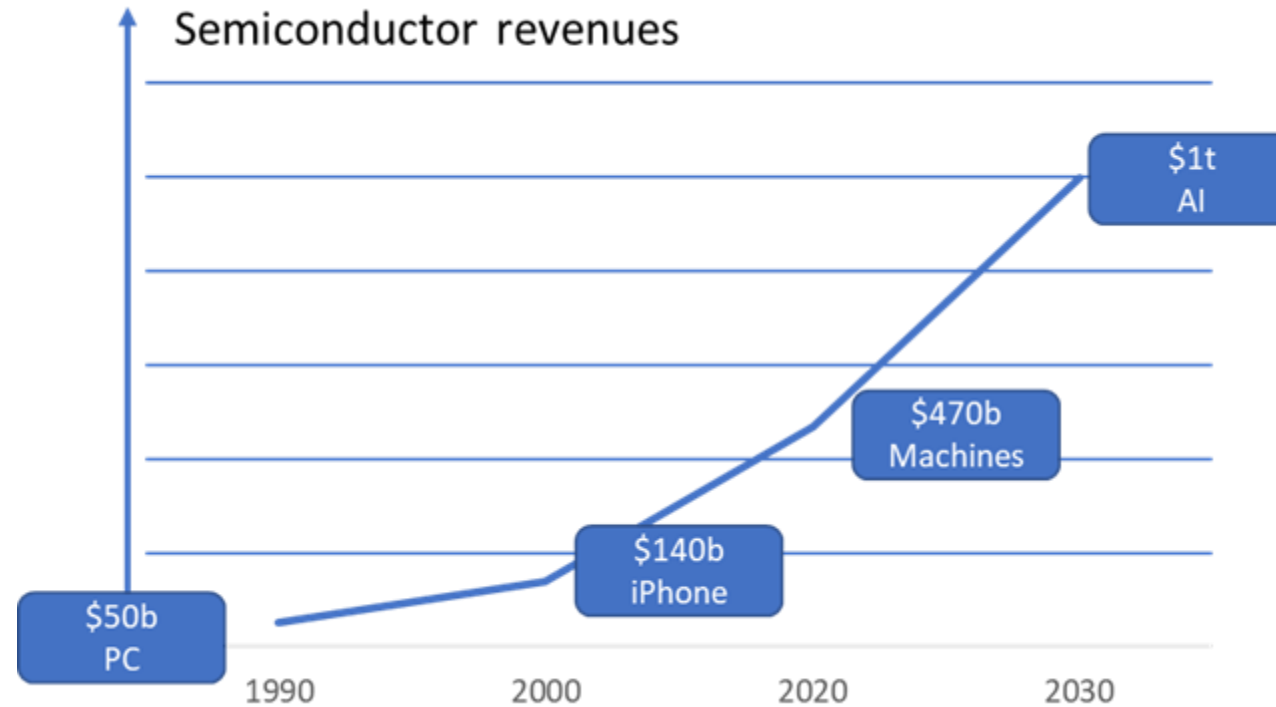
Business, Energy and Industrial Strategy Committee
Tuesday 7 June 2022 Meeting started at 10.17am



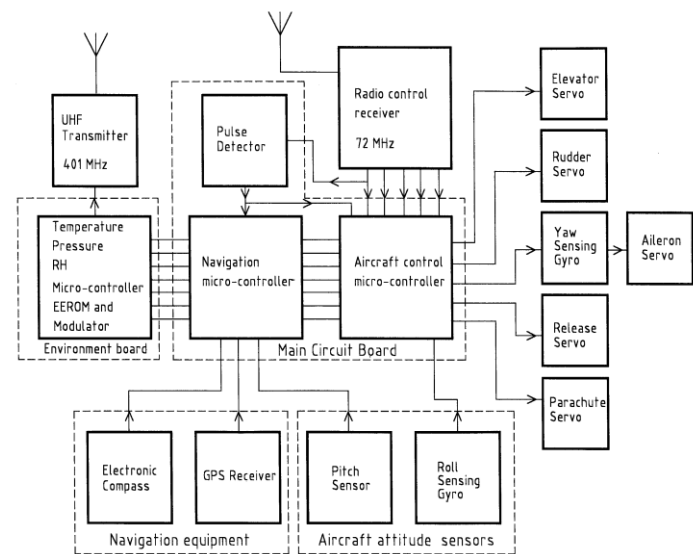
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[The Semiconductor Industry in the UK - Written evidence - Committees - UK Parliament](#)

Mega trends



Electronic systems

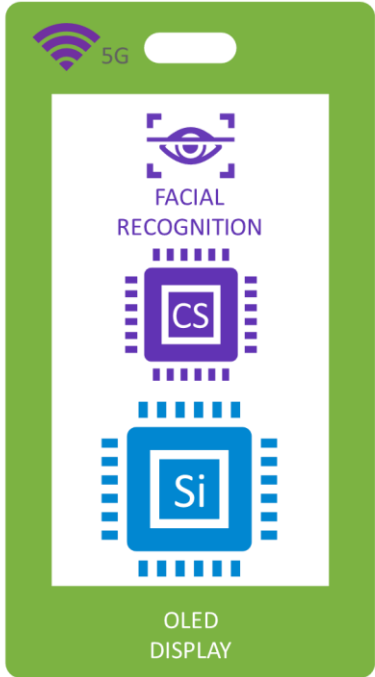


Electronic system	Biologic equivalent
Microcontroller / microprocessor	Brain
Memory	Memory (part of the brain)
Software	Neuron interconnect
Sensor(s)	Eyes, ears, tongue, etc
Servo	Arms, legs, etc
Transmitter / receiver	Vocal chords / ears
Battery	Muscles / body fat

Semiconductors – segmented by material

Silicon (Si) semiconductors	Compound semiconductors (CS)	Other semiconductors (2D, organic, thin film)
Discrete transistors	Power transistors (MOSFETs etc)	Displays (laptop, phone)
Logic	RF amplifiers	Solar panels (perovskites)
Amplifiers	Lasers	Novel flexible microprocessor demonstrated by ARM/PragmatIC Flexible Processors? Arm and PragmatIC Push Flexible Electronics Up A Level - News (allaboutcircuits.com)
Microcontrollers / microprocessors	Imaging	
Mixed signal	Single photon sources (quantum)	Novel sensors (graphene)
	Single photon detectors (quantum)	

Electronic systems



- Silicon (Si): main functions, typically 70-80% of semiconductor value
- Compound (CS): specialist functions, typically 10-20% of semiconductor value
- Other (OLED): display functions, typically 5-10% of semiconductor value

Examples

Product	Manufacturing cost	Semiconductor value	Si (%)	CS (%)	Other (%)
iPhone	\$570	\$350	80%	10%	10%
Tesla powertrain	\$3,900	\$1,950	20%	65%	5%
Data centre server	?	\$5,600	90%	>5%	<5%

[Apple iPhone 13 Pro Teardown | TechInsights](#)

[PowerPoint Presentation \(cargroup.org\)](#)

[PowerPoint Presentation \(appliedmaterials.com\)](#)

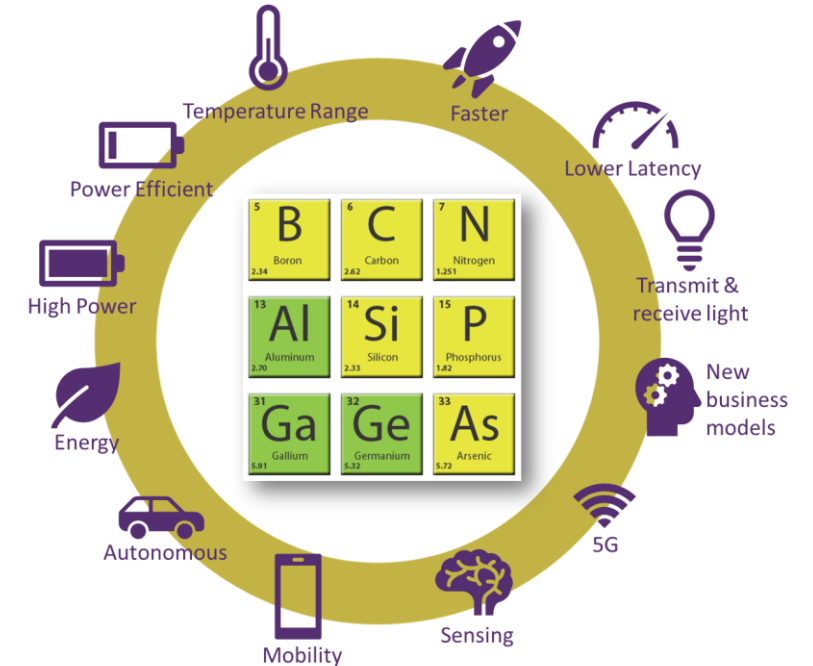
Silicon semiconductors – segmented by lithography

Category	Lithography or node (smallest transistor)	Typical chips	Cost to build a fab
Legacy Introduced before 2000	> 90nm Up to 10m transistors per chip	From single discrete transistors that switch power to complex chips with millions of transistors capable of running basic software	< £100m
Mainstream Introduced between 2000 and 2010	28nm – 90nm Up to 1bn transistors per chip	Highly functional chips capable of processing complex signals and running complex software	£200m – £1bn
Leading edge Introduced after 2010	< 28nm Up to 100bn transistors per chip	Extremely complex chips that may combine multiple mainstream chips in one device, capable of running complex software	\$5bn – \$20bn

Lithography refers to the dimension of the transistor, which is the building block of electronics. Transistor dimensions are measured in nanometres (nm). As the lithography size decreases, more transistors can be fabricated on a chip, creating more functionality on the chip.

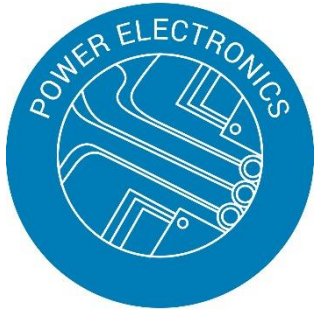
Silicon vs compound semiconductor chemistry

Type	First element	Second element
Binary III-V (most important)	Group III (aluminium, boron, gallium and indium)	Group V (antimony, arsenic, nitrogen, phosphorous)
Binary II-VI	Group II (cadmium and zinc)	Group VI (oxygen, sulphur, selenium and tellurium)
Binary IV-VI	Group IV (lead and tin)	Group VI (sulphur, selenium and tellurium)
Binary V-VI	Group V (bismuth)	Group VI (tellurium)
Binary II-V	Group II (cadmium, zinc)	Group V (antimony, arsenic and phosphorous)



- Silicon is a single element: possible to make large, very pure wafers
- CS are a combination of 2 or more elements: more difficult to control

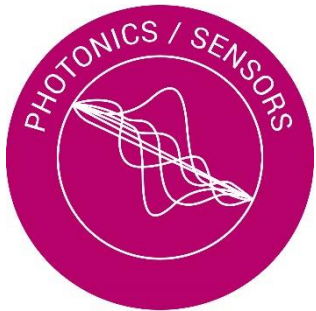
Compound semiconductors outperform silicon in 3 areas



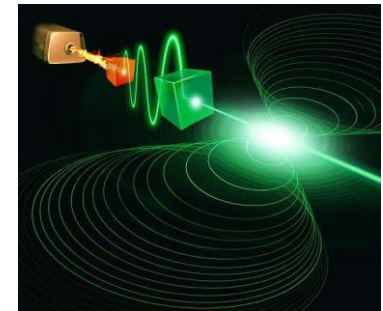
Power: electric vehicles, smart grids
Eg GaN and SiC



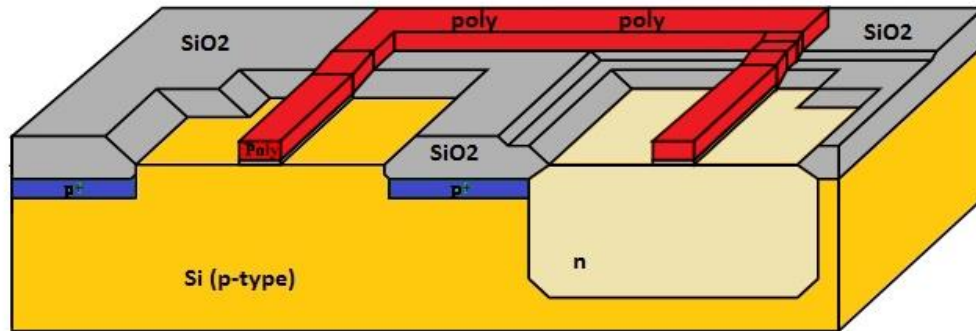
Speed: satellite communications & 5G
Eg GaAs and GaAs



Light: quantum, imaging
Eg InP and CdT

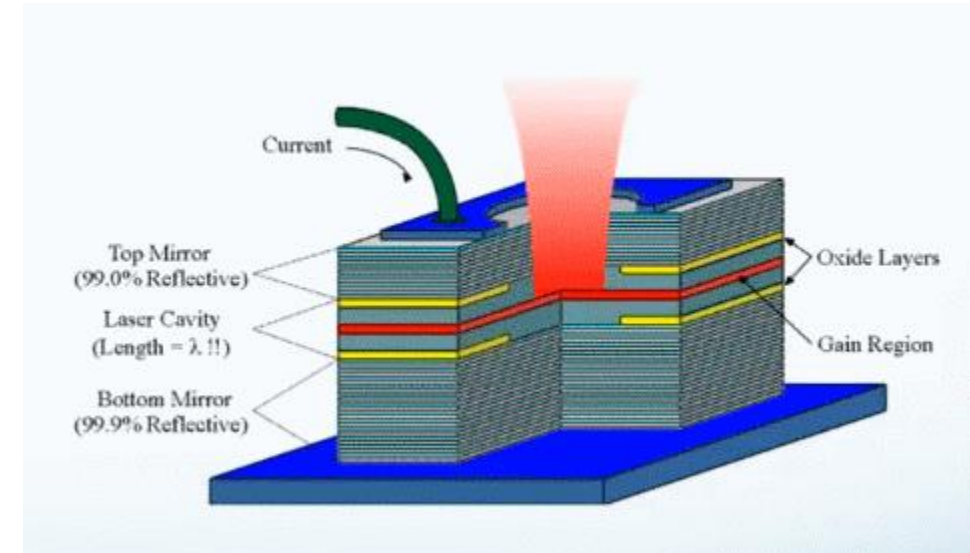
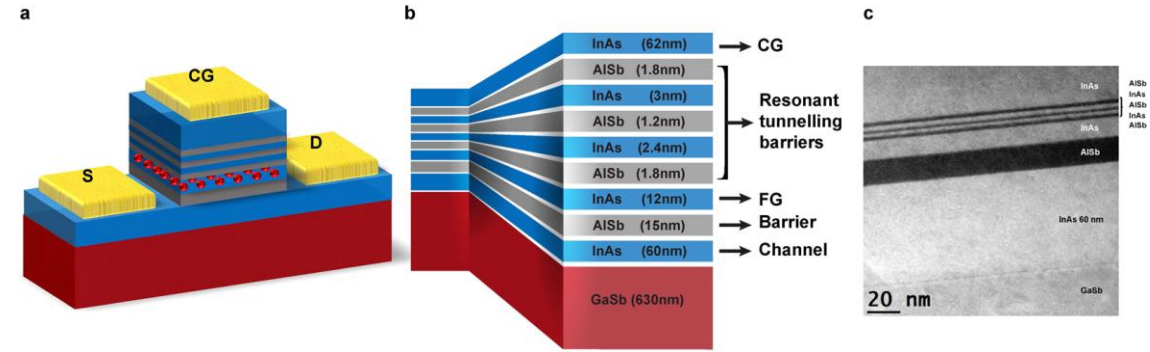


Silicon vs compound semiconductor processing



3D view of the Silicon Wafer after depositing the Poly layer. There are 2 Active Region (For PMOS and NMOS), Isolation Region (which consists Field Oxide), Gate Oxide and Poly layer.

Silicon processing tends to be planar / lateral:
up to 60 billion transistors per chip



CS processing tends to be 3D: single or few
special function devices (eg lasers) per chip

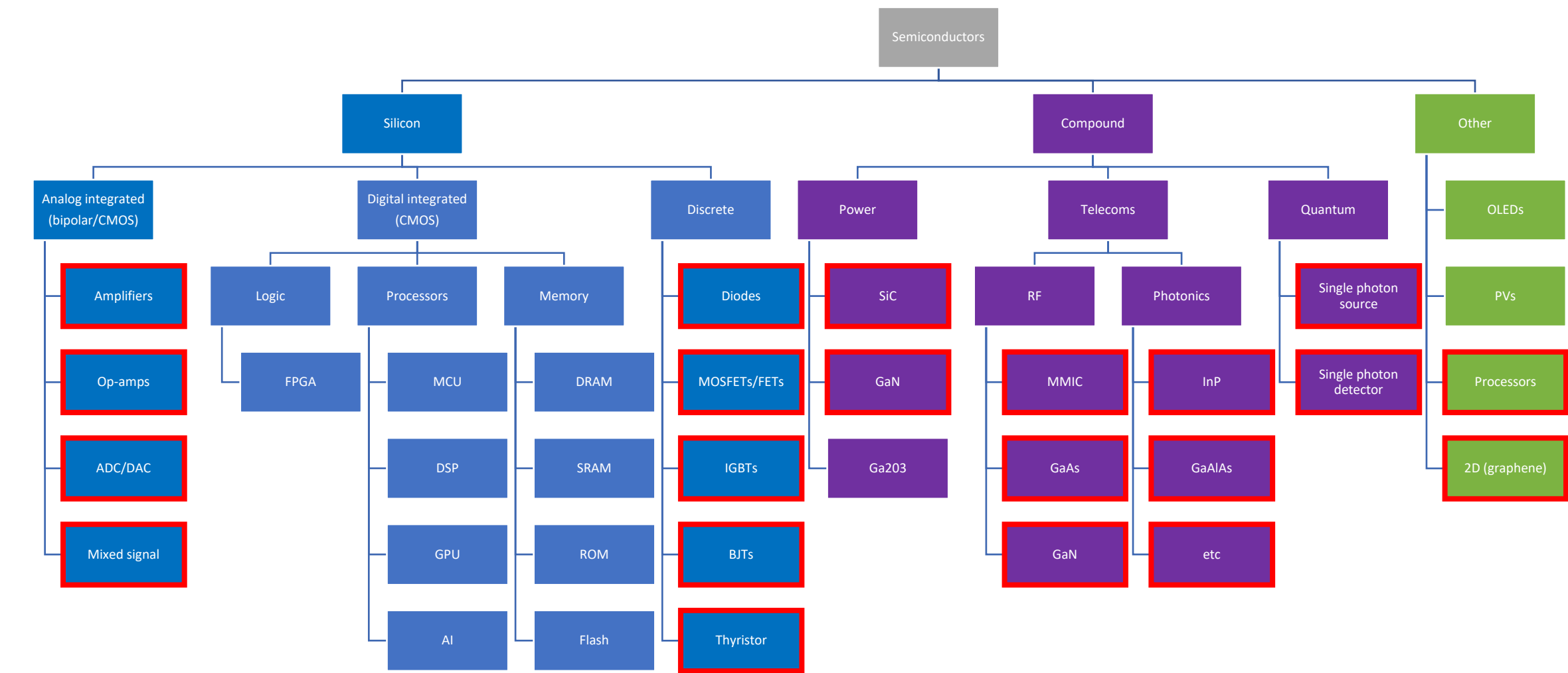
Compound semiconductors – segmented by application

Category	Typical chips	Typical applications
Power (eg GaN or SiC)	Single power transistors or arrays of power transistors	Used for power electronics in electric vehicles and smart grids
Speed (eg GaN or GaAs)	High frequency amplifier chips	Used to generate radio frequency (RF) signals for 5G, satellite communications and defence applications such as RADAR
Light (eg InP or GaAs)	Lasers, sensors, photon sources and detectors	Optical communications, missile guidance and quantum applications

'Other' semiconductors – segmented by application

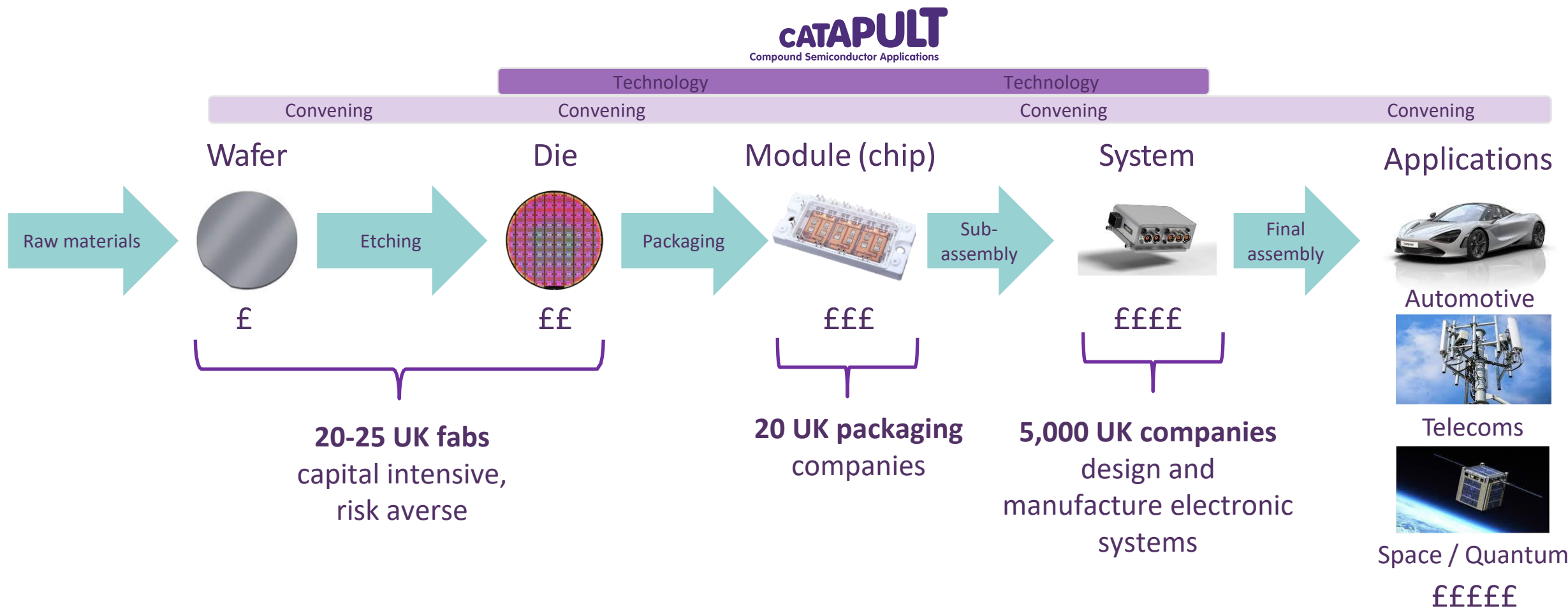
Material / technology	Typical chips	Typical applications
OLED and AMOLED	Large area displays	Displays for laptops, smart phones and smart TVs
Perovskite	Large area solar panels	Solar panels
Thin film	Flexible computer chips – lower cost than silicon but limited functionality compared with silicon	Low-cost labelling of consumer products
2D (eg graphene)	Sensors	High precision monitoring in harsh environments such as nuclear reactors or CERN

Semiconductor taxonomy



UK fabrication capability

Semiconductor supply chains



UK fab capability

Business models:

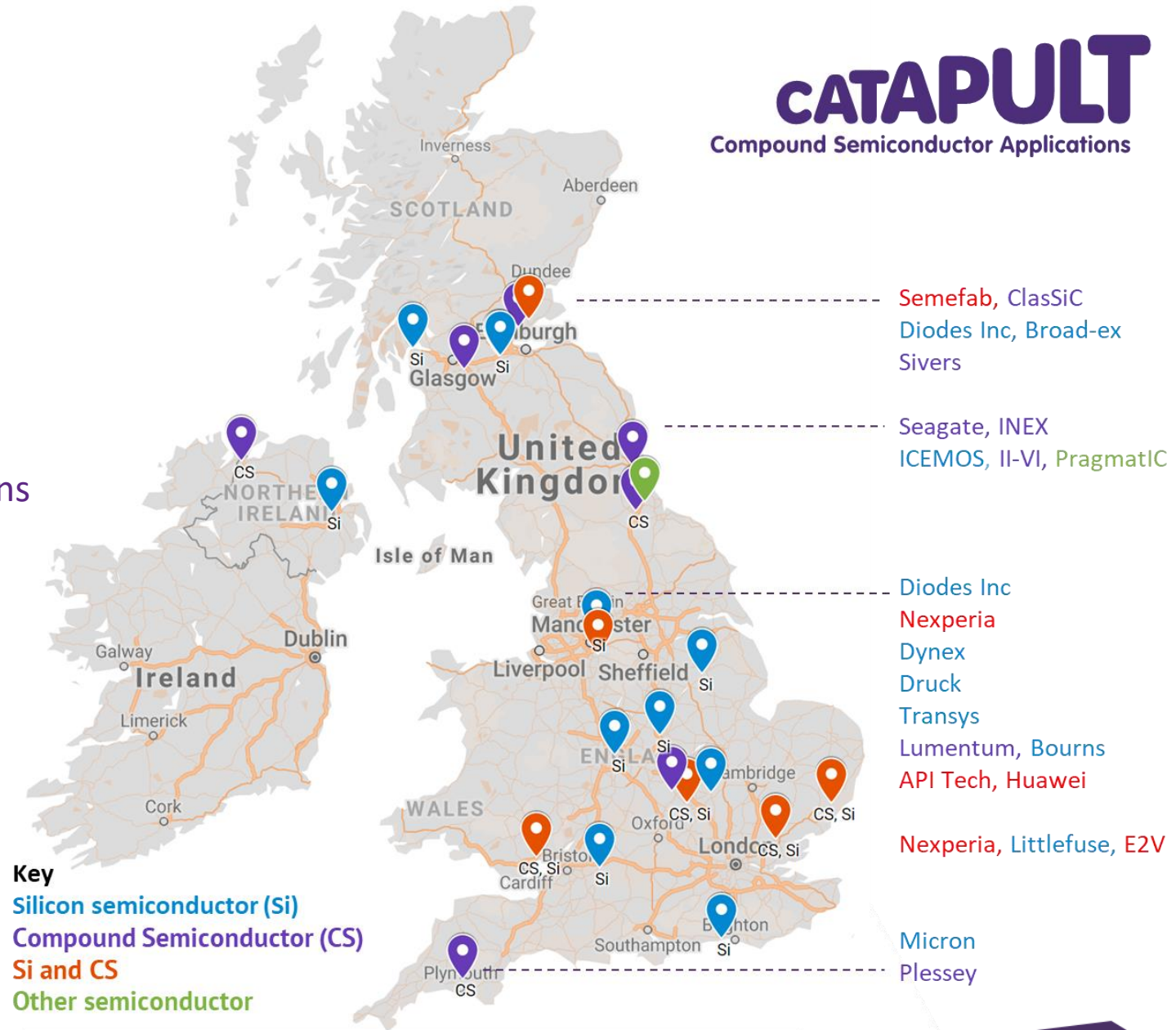
1 Integrated device manufacture (IDM)

- Research chip design and manufacturing process
- Manufacture 'badged' chips
- Eg Intel, Samsung, AMD

2 Open foundry

- Research manufacturing process
- Offer 'process design kit' (PDK) for 3rd party designs
- Manufacture chips to order, sell capacity
- Eg TSMC, Samsung

Trend: from IDM to open foundry



UK packaging capability

Packaging functions

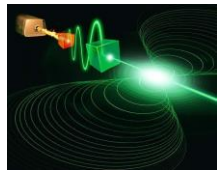
- Attaching electrical connections to semiconductor die (to be fitted to a printed circuit board PCB)
- Attaching die directly to a PCB
- Hybrid packaging: integrating semiconductor die with passive components to create a hybrid module
- Heterogeneous integration: integrating compound semiconductor 'chips' with silicon 'chips' to create a highly functional module
- Photonic packaging: aligning optical fibres or light guides with a photonic semiconductor, such as a laser or a detector, to create a photonic module
- RF packaging: coupling RF output to an antenna or array (eg metamaterial) to radiate the RF signal



UK system integration capability



Vehicle electrification (Net Zero)



Quantum



Telecoms



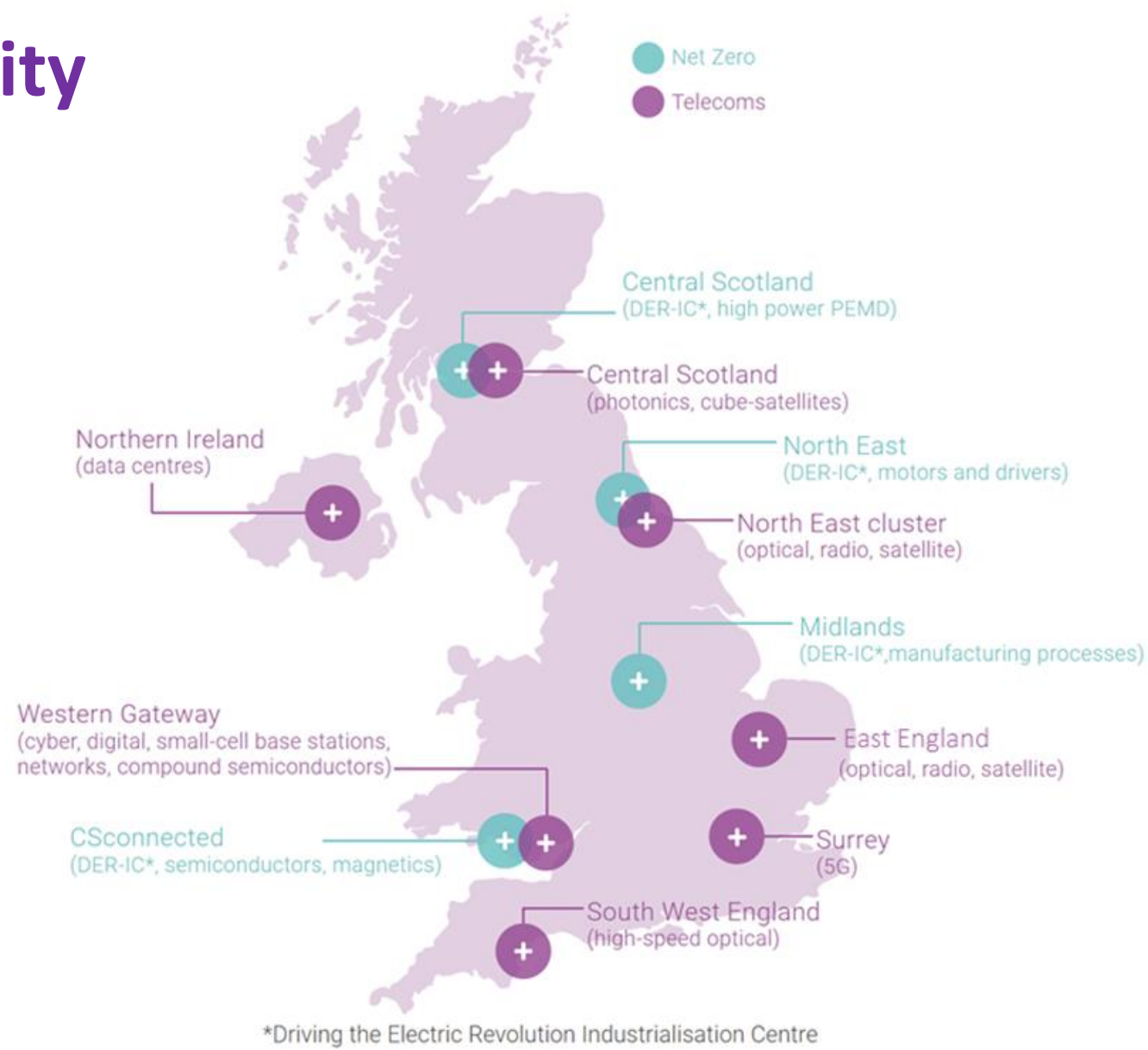
Smart energy grids (Net Zero)



Space



Defence



Silicon fabrication costs

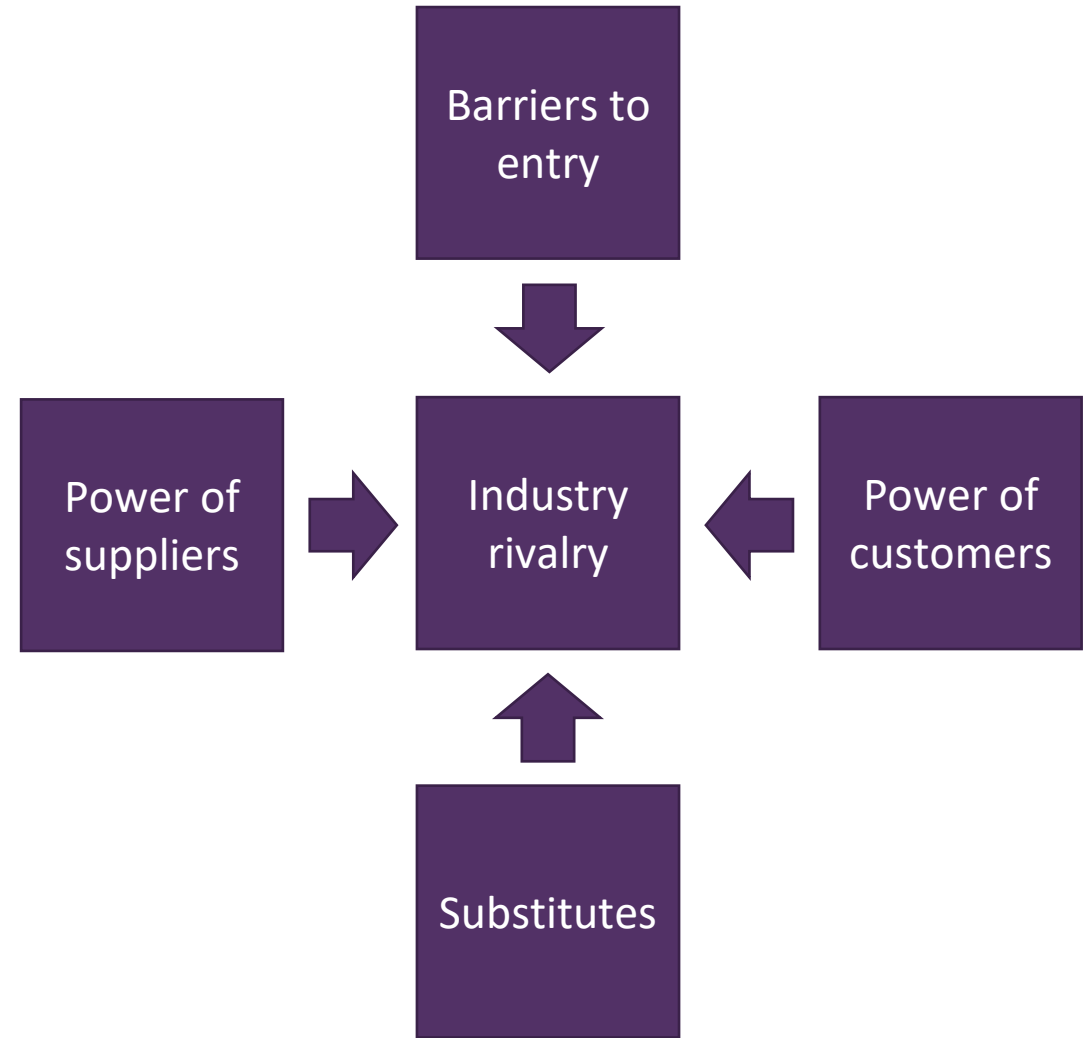
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The Economics of ASICs: At What Point Does a Custom SoC Become Viable? | Electronic Design

5 nm process - Wikipedia

Strategic advantage

- A company (or country) has a strategic advantage if it creates the conditions to secure success in a market (or non-market sector such as defence) in the medium to long term
- A technology or material confers strategic advantage if it is essential to achieving success in a market (or non-market sector), and there are no alternatives available



[Porter's five forces analysis - Wikipedia](#)

UK silicon capability

Silicon category	Device / application	R&D	Design	Fabrication	Strategic advantage
Legacy > 90nm	Logic, analog, MCU, MOSFET, diode, IGBT, FLASH	High	Medium: including design houses	High: some fabs capable of 1bn devices / year	Medium: alternatives available
Mainstream 28 to 90nm	MCU, DSP, FPGA, RAM	Medium: university research	High: good MCU and ASIC design	None	High: critical to all electronic products
Leading edge < 28nm	GPU, AI, IPU, FPGA	Medium: university research	High: world leading MCU design	None	High: critical to advanced electronic products

UK compound semiconductor capability

Compound semiconductor category	Device / application	R&D	Design	Fabrication	Strategic advantage
Power electronics	MOSFETs for electric propulsion	High: over £300m invested by EPSRC since 2006	High: start-ups, SMEs and larger companies	Medium: mix of low-scale and medium-scale production	High: critical to Net Zero
RF/ microwave	RF amplifiers for 5G / RADAR	High: over £300m invested by EPSRC since 2006	High: many SMEs and a few larger companies	Medium: low-scale production	High: critical to telecoms and defence
Photonics / quantum	Lasers + detector for optical comms	High: over £400m invested by EPSRC since 2006	High: many SMEs and a few large companies	Medium: high-scale wafer production but off-shored packaging	High: critical to telecoms, quantum and defence

UK 'other' semiconductor capability

Other category	Device / application	R&D	Design	Fabrication	Strategic advantage
OLED	Displays	Low	Medium	None	Low: alternatives available
Perovskites	Solar cells	High: good research at a few universities	Medium	None	Low: alternatives available
Thin film	Flexible MCU	High: leading university research	High: supported by silicon design ecosystem	High: world leading thin film fabrication	Medium: potentially disruptive technology
2D	Sensors	High: graphene and other 2D materials	High: mostly start-ups as it's an emerging technology	High: early stage companies	Medium: potentially disruptive technology

Integrated Review framework

Category	Definition
OWN	Where the UK has leadership and ownership of new developments, from discovery to large-scale manufacture and commercialisation. This will always involve elements of collaboration and access.
ACCESS	Where the UK will seek to acquire critical S&T from elsewhere, through options, deals and relationships.
COLLABORATE	Where the UK can provide unique contributions that allow us to collaborate with others to achieve our goals.

Dr Andy G Sellars
andy.sellars@csa.catapult.org.uk
[@andy_g_sellars](#)
07931 533 855

Tel: 01633 373121

Email: info@csa.catapult.org.uk

Twitter: [@CSACatapult](#)

Website: www.csa.catapult.org.uk

The CSA Catapult is a member of CS-Connected – the South Wales compound semiconductor cluster

www.csconnected.com