Ireland's role in the global semiconductor industry

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Board Chair's message

The new EU Chips Act and the €43bn in funding to develop the chip industry in the EU has introduced a new dimension to the semiconductor industry in Ireland. The same holds for the US counterpart of $52bn. Semiconductors are a critical technology, with vital industries and services depending on their availability. Safeguarding that availability, now and into the future, is an imperative for EU governments, including the Irish government, and like-minded countries. In this lies an opportunity for Ireland to greatly develop its already-strong semiconductor industry, and in doing so to strengthen and consolidate the whole tech ecosystem, an ecosystem that is of pivotal importance to Ireland's economic success.

As a leader in the semiconductor industry Ireland is well prepared to play its part in ensuring chip security within the EU and to capitalise on the doubling of the semiconductor market in the coming decade. We in Tyndall National Institute are in the vanguard, with over four decades of pioneering work in the area. Now as Tyndall Chair and formerly as VP of Analog Devices, directly responsible for chip factories in Ireland and the US, I have for decades advocated for the strategic importance of supporting semiconductor manufacturing and research in Europe and the US, which is now being recognized at EU and US governmental levels.

Tyndall National Institute calls on the Government to prioritise a National Chips Strategy for Ireland, and stands ready to meet the challenge of this crucial development for the country and the EU.

Dr Denis Doyle,
Board Chair, Tyndall National Institute

CEO's message

Recent global events have shown the urgent need to secure Europe's semiconductor future and at Tyndall National Institute we welcome the introduction of the new €43bn EU Chips Act . As CEO of Tyndall, Ireland's flagship research institute in ICT hardware and systems and a key R&D player in European semiconductor research, I am clear on the challenges and opportunities of this for Ireland. To maximise this opportunity, we call for the prioritisation of a National Chips Strategy, together with a corresponding Fund and Skills Pact, with the ambition of doubling the size of the industry by 2030. Utilising its rich network of global partnerships and depth of experience, Tyndall can play a pivotal role in furthering this ambition.

As a highly specialised and knowledge-intensive industry, growth will depend on generating new semiconductor knowledge and talent. Ireland has the advantages of a flexible, high-participation education system and Tyndall's success as a long-established dedicated national institute for semiconductors, microelectronics and photonics. This Paper calls for a Skills Pact for Chips to align higher-level qualifications with industry requirements and ensure a pipeline of skilled scientists to meet future need. In this regard Tyndall stands ready to act as a focal point for advanced training and skills.

Successful industrial policy in Ireland has resulted in a thriving semiconductor cluster, with Tyndall leading in semiconductor research and innovation over the past four decades. The Institute is going through an expansion supported by the National Development Plan and is aligned with the various initiatives of the EU Chips Act through R&D activities, innovation, thought leadership, and capital investment in infrastructure and pilot lines. We are positioned to play a central role as a Centre of Excellence in research and innovation, working with stakeholders in government, industry and education to maximise this opportunity and ensure Ireland retains its importance as a key part of the EU semiconductor value chain.

Professor William Scanlon,
CEO, Tyndall National Institute

Executive summary

Semiconductor technologies have transformed our society since the industrialisation of chip manufacturing six decades ago. Semiconductors have become so ubiquitous in product innovations that their continued development and availability are often mistakenly taken for granted. In reality, constant advanced research and development is required to maintain competitive advantage in design and manufacturing of semiconductor products, making this one of the most research-intensive industry sectors. In addition, semiconductor manufacturing, in particular wafer-scale chip production, requires very significant capital investment. The Covid pandemic and global chip supply shortages have put the spotlight on this critical technology sector, whose market is projected to grow from $590bn in 2021 to $1,065bn by 2030. This market in turn supports a broader ICT market of more than $5tn.

All major semiconductor economies – the USA, China, Taiwan, South Korea, Japan, Singapore, Canada and the UK– are pursuing investment and policy strategies to retain and advance their position. The EU will shortly introduce the Chips Act for Europe. The EU Chips Act comprises a comprehensive set of measures worth €43bn to ensure the European semiconductor ecosystem stays relevant and to safeguard the EU's strategic autonomy in the global supply chain of semiconductors.

Thanks to its successful industrial policy, Ireland has a longstanding thriving semiconductor cluster that directly employs 20,000 people and will generate an estimated revenue of about €15.5bn in 2023. Today, Ireland has significant European prominence, with the continent's most advanced semiconductor volume manufacturing capability, a legacy node fabrication plant and a strong chip-design sector, including major design activities in mixed-signal, automotive, communications and power. These successes are supported by a flexible, high-participation rate education system and the Tyndall National Institute, a long-established dedicated national institute for semiconductors, microelectronics and photonics. Notwithstanding government supports, the outlook for Ireland is not guaranteed to be positive. In the context of a market that will double in size over the next decade and a global reshaping of the semiconductor value chain due to geopolitical changes, growth of the Irish manufacturing sector of computers, electronics and optical components cannot be taken for granted.

For Ireland to capitalise on the opportunity presented by the global reshaping of the chip supply chain, there needs to be a national Chips Strategy with the ambitious target of more than doubling the size of the semiconductor industry in Ireland by 2030. To this end, we recommend taking action around five specific goals:

Providing direction

Recognition of semiconductor manufacturing and design activity in Ireland as a separate, discrete industry sector. The establishment of a High-Level Group across government, industry, research and education to develop and oversee the strategy for the sector, and oversee the implementation of the resulting action plan;

Mobilising the innovation ecosystem

Transformation of the Irish semiconductor and chip technology industry by creating a Stakeholder Alliance with a whole-value-chain approach to maximise the opportunities for investments of scale and also the creation of a fertile environment for SMEs, start-ups and scale-ups;

Creating a sustainable knowledge workforce

Introduction of a 'Skills Pact for Chips' with a holistic view of higher-level qualifications in sync with industry needs and incorporating outreach elements to ensure a healthy future skills pipeline, and to position Ireland for both indigenous and inward investment supported by the National Training Fund;

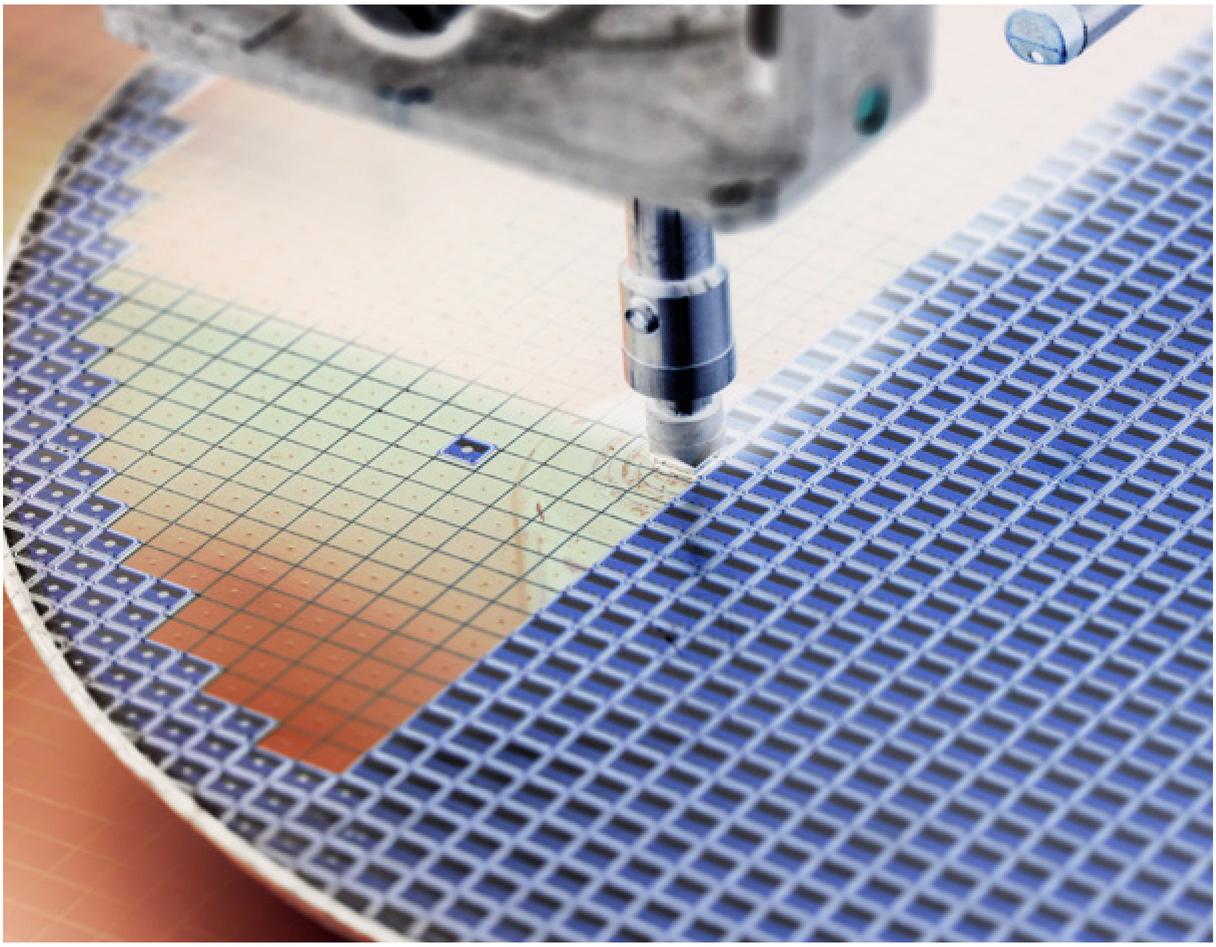
Sustaining research and innovation capacity

In line with the ambition of Impact 2030, consolidation of existing and planned industry supports, national science funding and other R&D public funding streams into a national 'Chips Fund', co-financing EU funding and leveraging strong private sector R&D investments;

Catalysing innovation

Active participation in the emerging European Pilot Lines – on FDSOI (Fully Depleted Silicon On Insulator) scaling, advanced nodes, heterogeneous integration and others – in the areas of More-than-Moore technologies (e.g., magnetics and Micro-Electro-Mechanical-Systems on FDSOI), micro-transfer printing for heterogeneous integration and photonics packaging; bringing lab research, manufacturing and applications together in a Centre of Excellence of scale; providing a focal point for semiconductor research and innovation; providing sectoral access to state-of-the-art pilot lines, test and characterisation and experimentation facilities; and ensuring the seeding of future innovations through activities at low-to-medium technology readiness level.

Tyndall – as Ireland's flagship research institute in ICT hardware and systems and key R&D player in European semiconductor research – is well positioned to play a central role in the semiconductor value chain as a Centre of Excellence in research and innovation and a focal point for advanced training and skills. The increase in market demand and the growing need to address global challenges with ICT innovations underlie Tyndall's strategy to double in impact and footprint by 2030. Tyndall is aligned with the various initiatives of the EU Chips Act through our R&D activities, innovation excellence, thought leadership, pipeline of talent, and capital investments in infrastructure and pilot lines. Working in concert with government stakeholders and Irish industry partners and other ecosystem organisations, Tyndall will help ensure that Ireland retains its place within the global semiconductor and chip technologies industry.



The global semiconductor value chain and the EU chips act

Technology innovation and manufacturing has been driving the knowledge economy globally and has fuelled Ireland's economic prosperity in the last 30 years. At the heart of this technological drive lie semiconductor components and systems. Semiconductor electronic and photonic products underpin the whole biome of Power, Sense, Think, Communicate and Act. Since their industrialisation six decades ago, semiconductors have changed our society at a pace like no other technology in history. There would be no consumer electronics without semiconductors. And without semiconductor chips we would not be able today to run our homes, cars, energy grid, traffic management systems, hospitals or financial services. Semiconductors are also foundational for emerging innovations such as artificial intelligence, autonomous vehicles and quantum computing.

The Covid pandemic has clearly demonstrated our reliance on semiconductor technology. Furthermore, the market is projected to grow from $590bn in 2021 to $1,065bn by 2030 driven by the wireless (including mobile and edge-AI devices), computing and data storage, and automotive industries. At the same time, the recent chip shortages and geopolitical changes have increased pressure to address Europe's strategic autonomy in the global supply chain of semiconductors. The EU is heavily dependent on third-country suppliers, while its share of the global market has been steadily declining to roughly 7%.[1] This is alarming, in particular when all major semiconductor economies – USA, Taiwan, South Korea, Japan, Singapore, Canada, UK and China – are preparing for the $1tn market.

The emergence of the large software platform companies along with the ongoing digitisation of economies, has led to unprecedented demand for semiconductor chips. This demand has not been met in tandem by capacity installation due to the large investment required and the timescale to achieve a return. Resulting consolidation of the semiconductor industry has gathered pace significantly in the last decade to the extent that there are now only three, arguably four, companies technically and financially capable of continuing the Moore's Law curve for the next generation of technology. None of these is European and only one is US-founded (Intel). For over three decades the backend processing – packaging and test, which can constitute up to 50% of the cost of an IC – had been outsourced to East Asia, China in particular. While the labour content of these steps has diminished with automation, and hence the attraction of low labour cost economies is reduced, the bulk of the installed capacity remains in East Asia.

As a result, in February 2022 the European Commission proposed the European Chips Act, a comprehensive set of measures worth €43bn to strengthen the EU's semiconductor ecosystem.[2] Meanwhile, in January 2023, the Industry and Energy Committee of the European Parliament adopted two draft bills on the EU Chips Act and its R&D companion on the 'Chips Joint Undertaking' ('Chips JU').[3] A political agreement on the European Chips Act between the European Parliament and the EU Member States was reached on April 18th 2023.[4] For Europe to strengthen its semiconductor ecosystem and regain market share, the EU Chips Act builds on the three pillars of R&D capacity, production and policy (Figure 1). Its proposals target:

- Investment in next-generation technologies; access across Europe to design tools and pilot lines for the prototyping and testing of and experimenting with cutting-edge chips;
- Certification procedures for energy-efficient and trusted chips to guarantee quality and security for critical applications;
- A more investor-friendly framework for establishing manufacturing facilities in Europe;
- Support for innovative start-ups, scale-ups and SMEs in accessing equity finance;
- Fostering skills, talent and innovation in microelectronics;
- Tools for anticipating and responding to semiconductor shortages and crises to ensure security of supply;
- Building semiconductor international partnerships with like-minded countries.

1 Europe headed towards 5% share of global chip production (eenewseurope.com)
2 European Chips Act (europa.eu)
3 Semiconductors: MEPs adopt legislation to boost EU chips industry | News | European Parliament (europa.eu)
4 Commission welcomes agreement on the European Chips Act (europa.eu)

The European Chips Act and its US equivalent of $52bn are critical for the future of the twin Green and Digital Transition and provide a great opportunity for Ireland's technology sector, from semiconductors and IT hardware to software and digital services. These chips initiatives are an inevitable response to two decades of outsourcing and underinvestment in semiconductor technology and capacity based on an overall lack of understanding of the dependence of our economies on the continuation of Moore's Law. Support through the Integrated Productions Facilities and Open EU Foundries for building large-scale fabs to produce the latest processor and memory technology chips is certainly welcome.

However, this does not reduce the EU's dependency overall as the chip shortages are not confined to processors and memory products. The supply chain pressure is across a broad range of semiconductor chips, components, sensors and actuators, so-called More-than-Moore technologies used in every piece of equipment. In technology terms, there is a need to also invest in capacity for legacy nodes and in specialised nodes (e.g. higher voltages). Packaging and integration technologies (e.g., heterogeneous integration) will play an even more important role in the coming decade as the limitations of Moore's Law will be offset by new post-fabrication technologies. In addition, automation and smart manufacturing can unlock the potential to relocate a percentage of the world's capacity in Europe.

Semiconductor fabrication facilities rely on a large number of diverse, highly specialised and expensive equipment sets. Indeed, the supply of semiconductor equipment is a current strength of Europe, as it hosts many leading names, e.g., ASML, ASM, Evatec, Aixtron, among others. The EU Chips Act must extend to supporting the ongoing development of semiconductor equipment and more importantly the science behind the processing steps that these equipment sets perform. Leading-edge research and innovation across the entire spectrum mentioned here is vital as we look beyond 2030. A one-off 2030 target will not create a sustainable semiconductor industry in Europe without continued investment in Research and Innovation.

Figure 1: The three pillars of the EU Chips Act and the initiatives under each pillar targeting increased R&D capacity, production and policy coordination

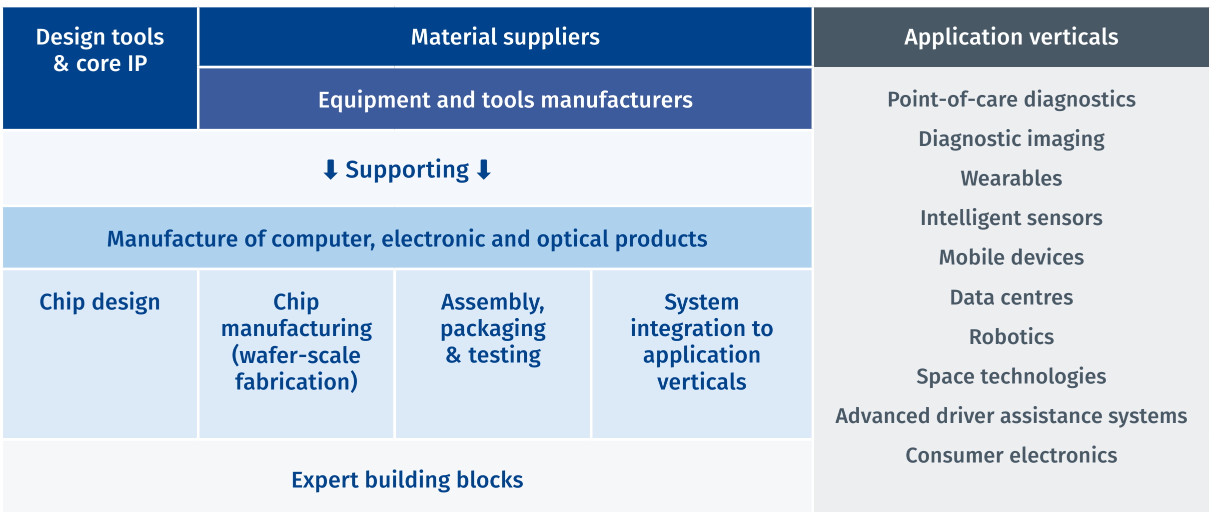
PILLAR 1	PILLAR 2	PILLAR 3
Chips for Europe initiative	**Security of supply**	**Monitoring and crisis response**
Infrastructure building in synergy with the EU's research programmes (Chips Joint Undertaking - €11bn)	First-of-a-kind production facilities (Open EU Foundries and Integrated Production Facilities - €30bn)	Monitoring and alerting
Support to start-ups and SMEs (Chips Fund - €2bn)		Crisis coordination mechanism with Member States
		Strong Commission powers in times of crisis
R&D Capacity	**Production**	**Policy**

The semiconductor industry in Ireland

Ireland is well positioned in the European and global semiconductor ecosystem thanks to its strong ICT industrial base and R&D excellence in the sector. Ireland has played a central role in the European semiconductor landscape for over 35 years. Starting with the establishment of the first semiconductor packaging plant by NEC in the 1980s – a crown jewel for semiconductors at the time – other semiconductor companies also arrived in the country in that period. These include Intel and Analog Devices, which subsequently grew into significant employers for the region. Today, Ireland presents a strong ICT cluster, hosting key players along the semiconductor value chain (Figure 2). Examples include: Cadence, Synopsys and Siemens EDA in Design Tools and IP; Qualcomm, Qorvo, MACOM, AMD Xilinx in Chip Design; Analog Devices, Intel, Microchip, Seagate, onsemi and Infineon in semiconductor manufacturing;[5] other manufacturers such as onsemi, Infineon and Renesas have design centres in Ireland; Henkel, J&J, Merck in Material Suppliers; Applied materials, Lam Research, Tokyo Electron and ASML in Manufacturing Equipment; and Tyndall in R&D.

The semiconductor sector in Ireland employs over 20,000 people, with about 6,500 of the jobs in highly skilled technical roles and about 3,000 of these in excellent research and development (R&D).[6] At an average fully loaded cost of about €100k per job, this generates economic activity of the value of €2bn. R&D spend alone is estimated at about a quarter of this value. At approx. €450m, this alone provides 10% to Ireland's fragile R&D expenditure as a whole (was €4.5bn or 1.06% of GDP in 2021)[7] and is one of the largest contributions of private R&D. In addition, revenue from activity in the Irish sector in the manufacture of computer, electronic and optical products is projected to amount to about to €15.5bn ($16.95bn) in 2023.[8] Taking into account the chemical and logistics industries, and other support services, there is a 2x multiplier of the total numbers for employment

Figure 2: The semiconductor value chain and examples of target applications.



5 It is noted that the manufacturing capacity of Seagate, onsemi and Infineon is located in Northern Ireland and overseas.

6 Electronics-Sector-Resources-Skills-Needs-Report-Rev5.1-Web-Optimised-1.pdf (midasireland.ie); According to the Labour Force Survey from the CSO under the NACE code Rev. 2 26 'Manufacture of computer, electronic and optical products' in 2020 there were 27,600 people employed in the sector constituting 16.6% of employment in the Digital sector and 1.2% of the total.

7 Statistics | Eurostat (europa.eu)

8 See Computers - Ireland | Forecast (statista.com); also, Statistics | Eurostat (europa.eu)

and economic activity secured by the thriving semiconductor business in Ireland.[9] **However, while the Irish semiconductor cluster looks strong, action is required to maintain and strengthen Ireland's position in semiconductors and to exploit the current opportunities as the global semiconductor market is projected to exceed one trillion US dollars by 2030.[10]**

Ireland can and must build on its strengths in chip design, deep-tech, smart manufacturing and chip fabrication to strengthen and grow its technology sector. The Irish economy grew by 12.2% in 2022 – nearly four times the EU or Euro area average – despite the backdrop of international slowdown and price pressures caused by the global energy crisis. It is recognised that this success is owed to the multinational sector, to which the semiconductor cluster contributes significantly both as an exporter and a support for many of the large industries, such as chemical and material suppliers.

Today, Ireland hosts the only Intel Fab in Europe – and Intel's largest outside the US – with advanced node manufacturing capability. Fab 24 in Ireland was established in the first global wave of semiconductor expansion in 1989 and employs more than 5,000 people at its ever-expanding 360-acre Leixlip, Co. Kildare facility and at a site at Shannon, Co. Clare. The most recent expansion investment of €5.5bn will establish Fab 34. The new Fab will enable the production of Intel 4 technology, the equivalent of a technology node using the 7nm lithography process to pattern semiconductor chips.[11] This technology will be the first Intel node using extreme ultraviolet lithography (EUV), a key-enabler for advanced sub-10nm nodes. The EUV system – a most complicated tool consisting of 100,000 parts, 3,000 cables, 40,000 bolts and more than a mile of hosing – was installed and tested in late 2022 with an onsite team of 100 staff by the Dutch manufacturer ASML.

Another exemplar semiconductor manufacturing site on Irish soil is Analog Devices (ADI) in Limerick. The ADI Irish facility has had a fully integrated marketing, design and wafer-fabrication facility in Limerick along with full research and development capabilities in product and process design and development since its inception. The 1,300 employees in Limerick contribute annually to the launch of over 100 new products and advanced semiconductor processes. These products are designed in ADI's leading-edge 14,000m² European R&D Centre, which opened in 2015. Following over 30 years of semiconductor innovation and manufacturing since 1979, ADI announced last year the creation of 250 additional jobs over the next three years in its ADI Catalyst facility for innovation and collaboration. Most recently, in May 2023, ADI committed to the investment of €630m to triple capacity of wafer production at the Limerick site.

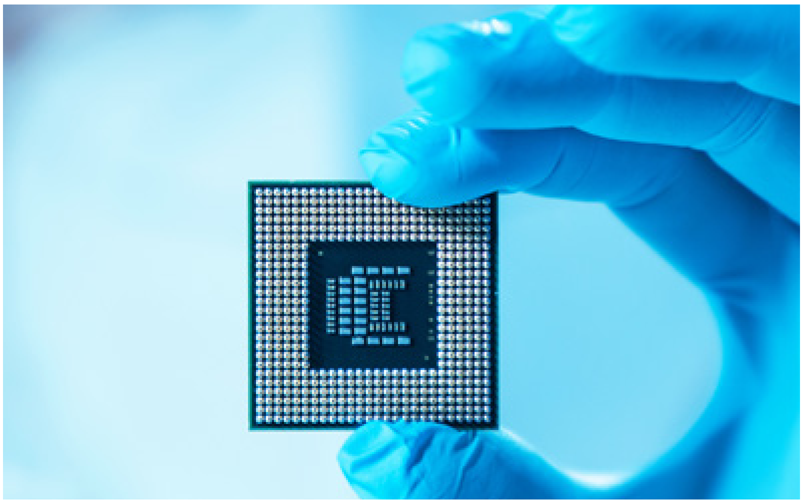
Foreign direct investment has also stimulated a significant indigenous semiconductor sector that has fuelled the creation of many Irish SMEs over the years. Many have scaled and through merger and acquisition contributed to the continuous growth and strength of the Irish semiconductor cluster. For example, the S3 Group was formed in 2006 after a management buyout from Philips and their expansion within a decade attracted significant interest to their divisions. While S3 Connected Health continues to deliver solutions in digital healthcare, S3 Semiconductors followed a series of acquisitions since 2018 that led to the establishment of Renesas – a Japanese semiconductor manufacturer – in Ireland. Decawave, Arralis, Movidius, Parthus, Redmere,

9 As an example Intel estimates that in addition to their 5,000 employees in Ireland a further 6,669 full time equivalent jobs and some 771 Irish suppliers are supported due to their business activities (Intel Celebrates 30 Years in Ireland | Intel Newsroom Ireland)

10 The semiconductor decade: A trillion-dollar industry | McKinsey

11 A nanometer (nm) is how much a fingernail grows per second. The technology node size does not refer to an actual feature size of a fabricated transistor but to generations of manufacturing processes that allow increased transistor density.

Powervation, ChipSensors, SensL and FireComms are few other Irish SMEs that have followed the same path to success. Currently, there are several Irish SMEs across the semiconductor value chain and supporting industries, e.g., AnDAPT, AnaTech, Easy IC, IC Mask Design and Chipright in Design, Mbryonics in Assembly Integration and Testing, Emutex in Supply of Embedded Software, Abrel Products Ltd in Equipment Supply. Many opportunities (and a proliferation of start-ups) lie also in semiconductor-based SMEs targeting non-semiconductor sectors such as agri-food, biopharma and digital healthcare.



In Europe, the production pillar of the EU Chips Act has already succeeded in attracting further non-European and European investment in semiconductor manufacturing. Intel (US) has announced a total investment of €33bn that, besides the Irish expansion plan, includes a mega-site semiconductor fab in Germany, a new R&D and design hub in France, and a state-of-the-art backend manufacturing facility in Italy.[12] TSMC (Taiwan), the world's leading semiconductor foundry,[13] is investing in a major fabrication facility in the US and is looking at establishing its first chip plant in Europe.[14] Samsung (South Korea) may also be seeking to build a mega-site in Europe in an effort to balance its supply chain.[15] Onsemi (US) is expanding its European silicon carbide (SiC) fab to increase production by 16 times despite going through a restructuring phase.[16] Wolfspeed just recently revealed plans to construct the world's largest and most advanced SiC device-manufacturing plant in Germany.[17] GlobalFoundries (US) has announced an expansion of the foundry site in Germany and a jointly-operated 300mm semiconductor manufacturing facility with the ST Microelectronics (Europe) in France to triple its capacity in Europe.[18] European companies such as Infineon[19] and Bosch[20] have also been expanding their 300mm fabrication capacity.

These investments along with the existing semiconductor ecosystem offer a unique opportunity for Ireland to redefine our positioning globally and ensure the future of the semiconductor industry on the island. Notwithstanding the consultation with government on the EU Chips Act[21] and supports from government agencies such as the IDA and EI, the outlook for economic activity in 'manufacture of computer, electronic and optical products' is not very bright. Modest growth is foreseen in the sector over the next few years.[22] For the Irish semiconductor industry to remain relevant and contribute to Ireland's competitiveness, Ireland urgently needs to define its own Chips Strategy with the ambitious target of more than doubling the size of the semiconductor industry in Ireland by 2030 in alignment with EU objectives and international trends.

12 Intel Announces Initial Investment of Over €33 Billion for R&D and Manufacturing in EU.
13 A foundry is a semiconductor facility that manufactures chips designed by customers and/or partner chip makers.
14 Chipmaker TSMC in talks with suppliers over first European plant | Financial Times (ft.com)
15 Samsung mulls new foundry plant in Europe, to expand outsourcing – KED Global (ampproject.org)
16 Onsemi expands its Silicon Carbide Fab in the Czech Republic
17 Wolfspeed Announces Plan to Construct World's Largest, Most Advanced Silicon Carbide Device Manufacturing Facility in Saarland, Germany | Wolfspeed; Wolfspeed to Build $3-Billion EV Chip Plant in Germany, Subsidy Approval Expected in Months (usnews.com)
18 STMicroelectronics and GlobalFoundries to advance FD-SOI ecosystem with new 300mm manufacturing facility in France | GlobalFoundries
19 EE Times Europe – Infineon to Invest €5B in Dresden 300-mm Fab
20 Bosch to invest $3b in European chip fabs, research • The Register
21 Public Consultation on the European Chips Act – DETE (enterprise.gov.ie)
22 Manufacture of Computers & Optical Products – Ireland | Forecast (statista.com)

Call for a national chips strategy

Tyndall, together with its research and industry partners, can drive the re-positioning of Ireland in the semiconductor value chain to benefit from the global upheaval in the chip supply chain and the EU Chips Act initiatives in particular. To this end, a **Chips Strategy for Ireland is urgently needed with the ambitious target of more than doubling the size of the semiconductor industry in Ireland by 2030.**

This opportunity can be materialised as growth for indigenous SMEs and the creation of start-ups/scale-ups, a stronger cluster of the ICT industry with increased FDI.[23] Particular focus should be put on the design and manufacturing capacities in Europe. These activities combined account for 74% of the value-add across the semiconductor value chain, while contributing to high-value employment in one of the most research-intensive industries.[24]

Specifically, an action plan for Ireland's Chips Strategy could aim to:

- Deliver design capacity, prototyping pilot lines and testing facilities to create new value chains between the micro/nanoelectronics and photonics technology sector and its strong digital service, medical devices, biopharma and agri-food industries;
- Utilise the Important Projects of Common European Interest (IPCEI) mechanism and, most importantly, the new possibilities offered by the Integrated Production Facilities and Open EU Foundries to grow the size and increase the number of chip manufacturing sites in Ireland and attract further FDI to this end;
- Leverage the European ecosystem to globalise its Research and Technology Infrastructure with a dedicated Competence Centre of scale;
- Lead in attracting and growing highly skilled talent in semiconductor technologies and applications through national and European training networks;
- Use the 'Chips Fund' to enable Irish semiconductor start-ups achieve scale.

As a starting point towards a 'Chips Strategy for Ireland', we recommend building a strategy around the following five goals.

Providing direction

If there is one lesson to be learnt from the European and global stage, it is that no single company, organisation or even government can transform the semiconductor industry alone. The EU Chips Act foresees the establishment of a European Semiconductor Board, composed of representatives of the Member States and chaired by a representative of the Commission, to advise the Commission and Public Authorities on the implementation pillars of the Act. Similar coordinated action is required between national stakeholders to capitalise on the Irish opportunity presented by the global reshaping of the chip supply chain.

Recognising semiconductor manufacturing and design activity in Ireland as a separate, discrete industry sector, we recommend the establishment of a High-Level Group across government, industry, research and education to:

- Articulate an Action Plan that aims to more than double the size of the semiconductor industry in Ireland;
- Oversee the strategy for the sector and the implementation of the resulting Action Plan.

It is envisaged that the Group will be relatively compact across the value chain for effectiveness and agility.

Mobilising the innovation ecosystem

Transforming the Irish semiconductor industry can only be achieved by bringing together key players from across the whole semiconductor value chain and applications sectors; actors from research institutions; networks of investors, incubators and accelerators; regional government and government agencies.

We recommend the creation of a broader Stakeholder Alliance to:

- Foster synergies for the creation of a fertile environment for SMEs and for start-up creation and scale-up;
- Maximise opportunities for growth and optimise the conditions for greenfield investments of scale in design and manufacturing.

23 FDI: Foreign Direct Investment
24 Strengthening the Global Semiconductor Supply Chain in an Uncertain Era – Semiconductor Industry Association (2021)

The Stakeholder Alliance is foreseen to be strongly involved in the implementation of the Action Plan by identifying existing gaps and the developments necessary for competitiveness of the Irish semiconductor cluster, as well as recognising bottlenecks, external triggers and opportunities for investments across the sector. Here, forums such as the MIDAS Industry Association for Microelectronics and Electronic Systems Design can be particularly effective.

Creating a sustainable knowledge workforce

The entire semiconductor industry relies heavily on highly talented people with imagination, ingenuity and innovative instincts. The widening gap between supply and demand of engineers with technical skills in semiconductors makes it clear that the companies will grow and go where the talent is. As an example, it is estimated that over 1,000 highly skilled R&D jobs have been lost to the electronics sector in Ireland for this reason.[4]

Deloitte has recently predicted that the semiconductor workforce will need to grow by more than 1 million additional skilled employees by 2030.[25] As well as engineers and PhD candidates, highly qualified industry technicians are needed for the future workforce of a sustainable high-value semiconductor industry in Ireland. In addition, the field of semiconductor and chip technologies is naturally multidisciplinary and broad based, as it covers atoms to materials, processing to devices, circuits and systems while requiring underpinning expertise in physics, chemistry, materials science, engineering, computer science and mathematics.

We recommend the development of a 'Chips Pact for Skills' supported by the National Training Fund to:

- Form the underpinning for a holistic view of the development of Higher-Level Qualifications across levels (Levels 7–10) and in sync with industry needs deriving from the Action Plan of the national Chips Strategy;
- Incorporate outreach to secondary education students and create industry-informed higher-education programmes with hands-on and/or research experiences and internships.

This action would ensure a healthy future skills pipeline, and position Ireland for both indigenous and inward investment.

Sustaining research and innovation capacity

The semiconductor industry is among the most research-intensive industries. The SFI-funded research centres and the EI-funded technology centres may provide a platform for sustained research and innovation capacity by enabling academic–industry collaboration at the national level. However, compared to other European countries, there seems to be a mismatch between the size of the semiconductor industry in Ireland and its participation in European R&D programmes. This is partially due to the fact that Ireland's semiconductor ecosystem differs from that of 'mainland' Europe. Thanks to Ireland's successful industrial policy, the ecosystem is primarily built around FDI, with R&D often residing overseas.

Another reason is that the European Commission (EC) sees co-investment by Member States as an essential tool to mobilise the necessary resources for achieving the grand ambition of the EU Chips Act. These co-investments are necessary for participating at the forthcoming Chips Joint Undertaking (JU) and for setting up competence centres, a design platform and pilot lines. At present there are insufficient incentives for Irish organisations to benefit from these large-scale EC

25 2023 Semiconductor Industry Outlook | Deloitte US

investments and the opportunities offered by partnerships at the European level. For example, there are three pilot lines foreseen in the near term, on leading-edge nodes, scaled fully depleted silicon-on-insulator, and heterogeneous systems integration. Their future as well as that of pilot lines in the longer term will depend on the scale of leveraged resources in the expressions of interest of the leading parties.

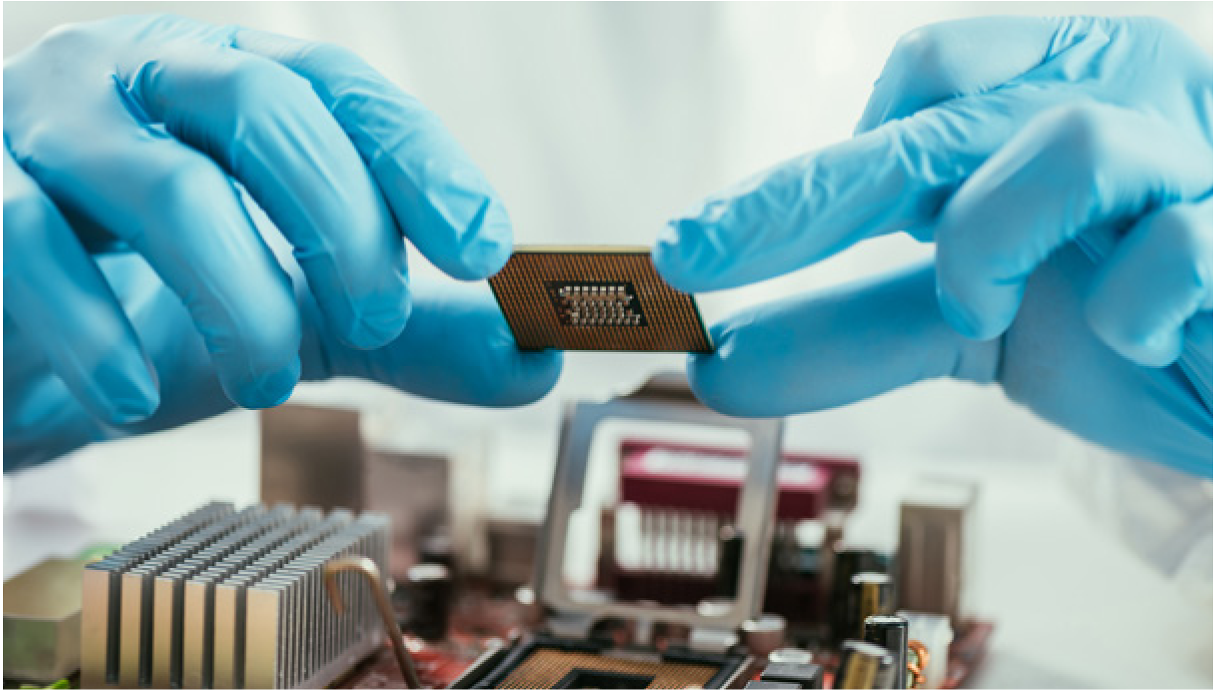
To match the EU funding and leverage strong private sector R&D investments, we recommend the establishment of a national 'Chips Fund' through the consolidation of existing and planned industry supports, national science funding and other R&D public funding streams. This more targeted effort will increase R&D capacity in Ireland and profit from the innovations generated, in line with the ambition of Impact 2030.

Catalysing innovation

Europe has yet to extract a significant return from the semiconductor value chain in proportion to Europe's historical key strengths in laboratory research and academia. To increase innovation capacity, the aim should be to bring lab research, manufacturing and applications closer together, that is, from Lab-to-Fab & App. At the national level, this means active Irish participation in the emerging Design Platform and European Pilot Lines in the areas of More-than-Moore technologies, photonics packaging and hybrid system integration, as well as providing a focal point for semiconductor research and innovation that interfaces effectively with the industry to harness new talent and excellence in research for industrial innovation.

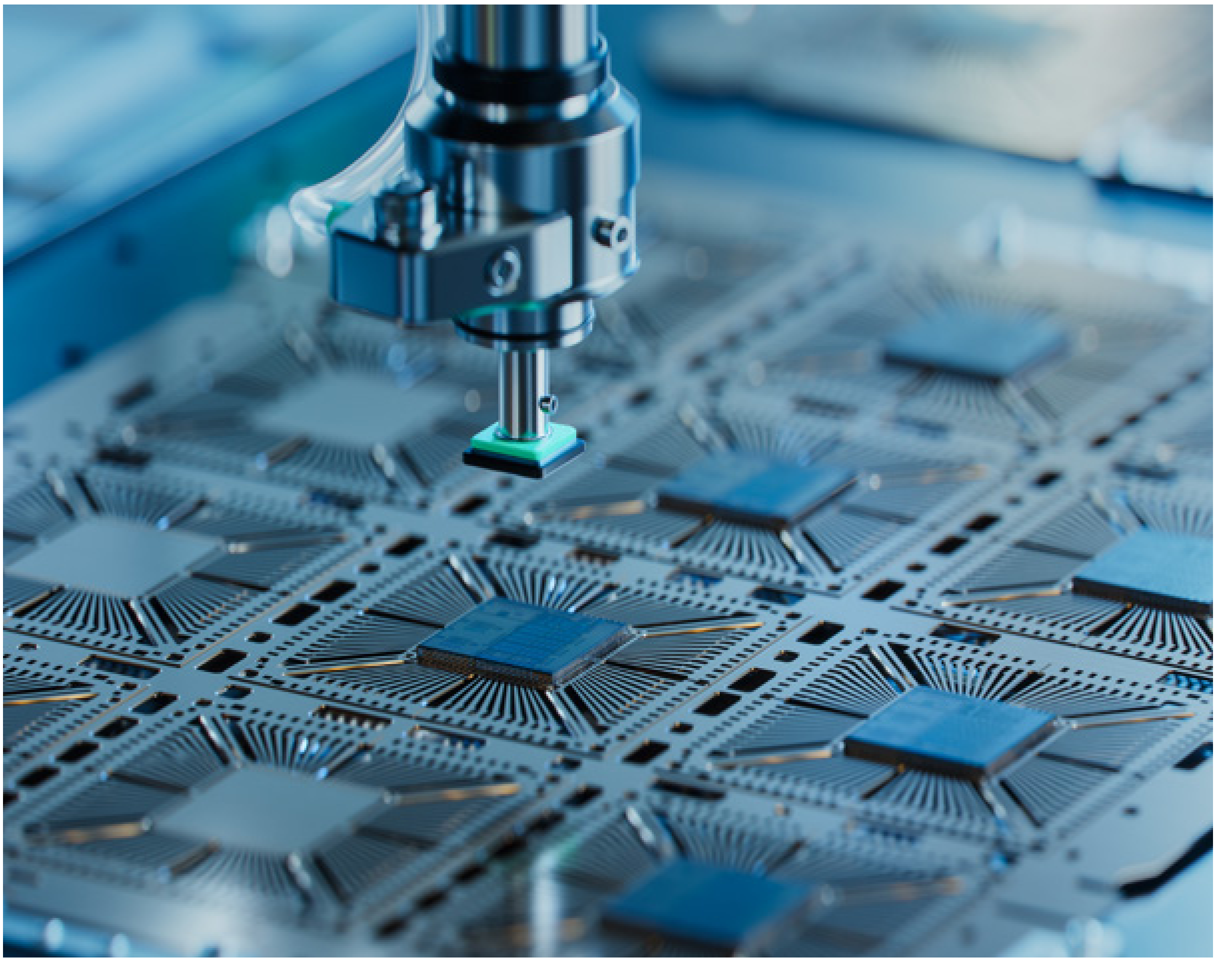
We recommend support for a range of activities at a semiconductor Centre of Excellence at scale to:

- Establish prototyping and low-to-medium volume manufacturing pilot lines, design platforms and module testing and experimentation facilities, and facilitate access to those;
- Sustain research activity at early-to-medium readiness levels with the aim of creating a pipeline of innovations for semiconductor technologies based on frontier knowledge;
- Provide leadership in knowledge transfer, development of highly specialised talent, and technological innovation in the semiconductor value chain and its application sectors.



Concluding remarks

Ireland's existing strength in the global semiconductor and chip technology sector is built on a significant heritage of both FDI and indigenous companies working across the full value chain from materials and manufacturing to circuit design and advanced applications. Within Europe, Ireland is at the forefront of leading-edge node manufacturing, and this will remain the case for some time. Other strengths include significant chip-design activities across the SME and multinational sectors, a nascent photonics industry and many other companies across the wider supply chain. Government investment in skills and research and innovation, including 40 years of investment in Tyndall, has matched the growth of the industry in Ireland and maintained a competitive edge in terms of investment by multinationals. However, the clear ambition of other European and other western countries to invest in semiconductors means that Ireland needs to double down on the development of all aspects of the sector, even to maintain its current share of business. A Chips Strategy for Ireland, and its realisation, will provide the focus and intervention needed to make the most of the short window of opportunity for both private and public organisations to work together and to properly position Ireland in the global semiconductor market.

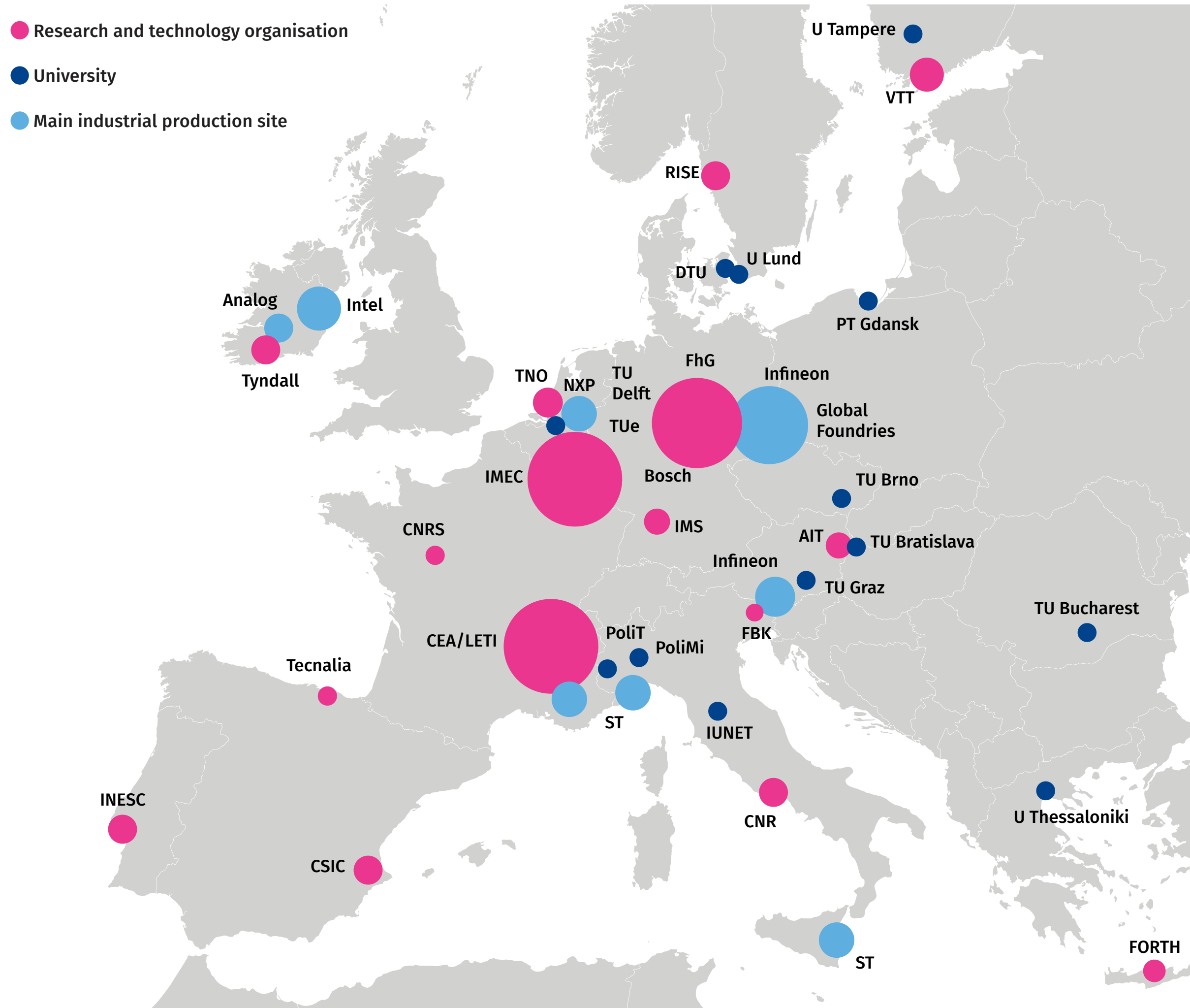


Further information

Tyndall's positioning in the semiconductor research & innovation value chain

Tyndall is an acknowledged key R&D player in the European semiconductor research and ICT ecosystem and Ireland's leading research centre in over 40 years of operations (Figure 3). Tyndall was established in 2004 as successor to the National Microelectronics Research Centre (NMRC), founded in 1981 following the opening of a silicon wafer-fabrication laboratory in 1979 to provide R&D and specialised training facilities for the semiconductor manufacturing industry. Tyndall has been a semiconductor research and supply partner to the European Space Agency since 1986 and is one of the leading space qualification competence centres in Europe. Tyndall is home to a multidisciplinary research community of over 600 staff, postgraduates students and industrial researchers-in-residence, and is Ireland's largest dedicated research institute. In terms of R&D funded by the EC in the area of ICT, Tyndall is in the top 5 EU RPO and #12 among all EU public research bodies including major RTOs such as imec, CEA-leti, and Fraunhofer Gesellschaft.[26,27]

Figure 3: *Key players in semiconductor R&D in the EU by type and size as indicated in the legend and circle areas. [Data taken from Ref. 27].*



26 RPO: Research Provider Organisation; RTO: Research and Technology Organisation

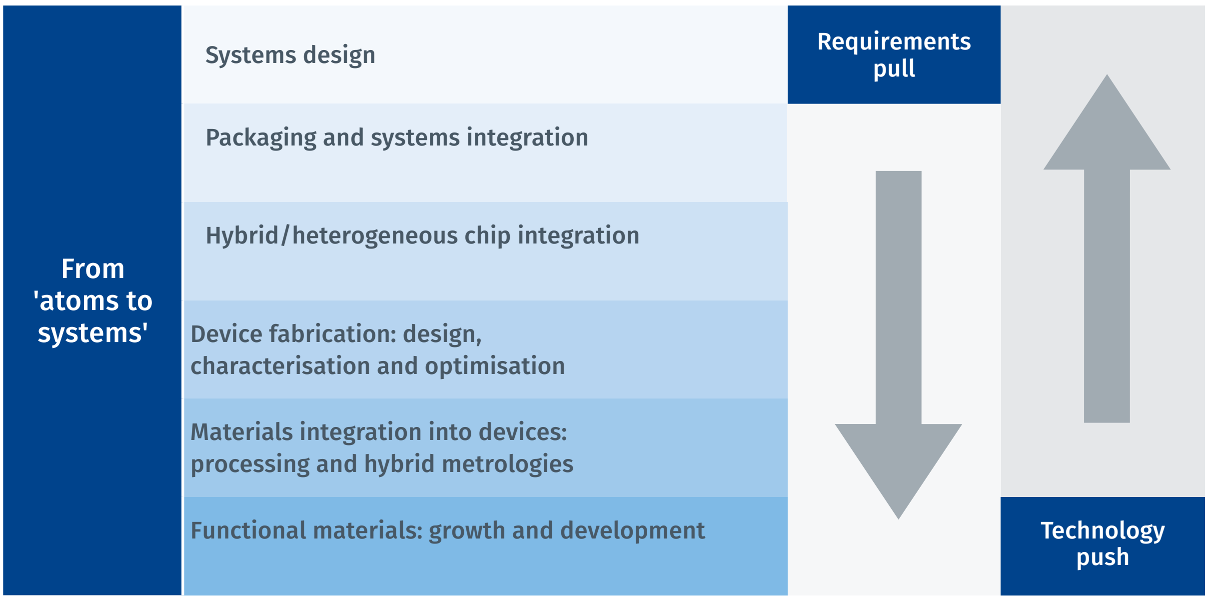
27 Funding & tenders (europa.eu); See also: Commission Staff Working Document 'A Chips Act for Europe' SWD(2022) 147 final - PART 2/4 SWD Chips Act v15 (europa.eu)

Tyndall is a national asset for Ireland's positioning in semiconductors. Tyndall brings together a repository of collective knowledge on semiconductors and unique high-capital infrastructure, with the vision to be a global leader for deep-tech innovation and impact through excellence in research. The cohort of industry researchers onsite evidences Tyndall's unique role in the semiconductor ecosystem in Ireland. More than 100 industry researchers from 16 different companies have access to Tyndall's unique infrastructure and research talent through their in-residence status. Of these, 11 are semiconductor companies and nine are SMEs.

With an ambitious growth strategy to double in size by 2030, Tyndall is in an excellent position to scale internationally as an R&D Centre of Excellence and support the growth of the Irish semiconductor industry. Our business linkages in Ireland include a vibrant community of SMEs (approx. 50% of our research engagement) and extend beyond semiconductor business directly to reach out to the application sectors of digital healthcare, medical technologies, energy and environment, and agrifood.

Tyndall addresses electronics and photonics technologies across the value chain – from materials and devices to circuits and systems. Figure 4 shows Tyndall's deep-tech stack for semiconductors. Our research activities cover the full innovation value chain from generation of basic ideas to challenge-driven technology formulation, and through further development and prototyping to technological and commercial feasibility. During the last five years, Tyndall has produced over 300 scholarly outputs per year. More than one-third of those led to publications in the top 10% journals in their field. Besides our research excellence in 'atoms to systems', we also take pride in our Lab-to-Fab & App approach.

Figure 4: Tyndall's deep-tech stack from Atoms to Systems enabling our 'Lab-to-Fab & App' approach. See Use Cases for examples of Technology Push from Lab-to-Fab and Requirements Pull Application Use Cases.



A major driver for research at Tyndall is 'Lab-to-Fab', that is, unlocking innovation and accelerating the translation from research ('Lab') to the design and manufacture ('Fab') of semiconductor products. Overall 9% of our scholarly output is co-authored with industrial partners, standing well above the Irish average of 5.7%. Tyndall is the top Irish organisation for licensing technology to industry – 95% of which is for semiconductor technologies – accounting for ~60% of national licence income and, pro-rata, on a par with the world's leading research economies for licence income. Tyndall's technology has been instrumental in the establishment of 22 start-up companies to date, of which several scaled-up and led to high-value acquisitions.

While the general spotlight is most frequently on Lab-to-Fab, at Tyndall we are also concerned with tackling major societal challenges through advances in scientific and engineering research on semiconductors. Figure 5 indicates several areas where our research is embedded in semiconductor technology solutions for the benefit of health and well-being, agriculture and food, climate and energy, and the digital socio-economic transformation overall.

Figure 5: Technology solutions for societal challenges underpinned by scientific and engineering semiconductor research at Tyndall.

Health and wellbeing	**AgriFood and environment**	**Climate and energy**	**Society and industry innovation**
• Diagnostic imaging • Point-of-care digital diagnostics • Minimal invasive surgery • Internet of medical things • Digital therapeutics • Wearables	• Intelligent and adaptive food production • Intelligent logistics and food quality monitoring from farm-to-fork • In-field diagnostics for plant health, animal welfare and health • Real-time soil-health monitoring • Water management and quality • Environmental remediation	• Carbon-neutral production • Energy efficient ict • Demand-side energy management • Smart energy grids • Smart waste management • Sustainable digital technologies	• Smart factories • Sustainable production • Intelligent buildings • Infrastructure management • Digital inclusion: 5g/6g communications, ar/vr • Space technologies for low-earth orbit comms and sensing

Tyndall alignment with chips act initiatives

Tyndall prepares to play a key role in the various chips initiatives, building on our excellent record of accomplishment in Europe, international network, and national position as Ireland's Centre of Excellence in semiconductors. In particular, Tyndall can drive activities in targeted challenge-driven R&D programmes and prepare for industrial development through advancing manufacturing processes and prototyping. The latter can be undertaken at our own pilot lines or jointly at the pilot-line sites of strategic partners. These activities underpin the innovation and production pillars of the EU Chips Act by sustaining the semiconductor innovation pipeline at early-to-medium readiness levels (see Figure 6). In the USA, the Microelectronics Commons[28] and the National Semiconductor Technology Center[29] are envisaged to play this role in the US Chips Act.

Furthermore, as the national repository of semiconductor knowledge the Tyndall community can support the underlying need for talent development and skills training across the full spectrum of needs. According to a recent report coordinated by SEMI Europe – the European branch of the global semiconductor industry association comprising companies involved in the electronics design and manufacturing supply chain – the current gap between supply and demand for engineers with technical skills in semiconductors keeps increasing.[30] The profiles sought after include skills in digital and analog design, heterogeneous system design, applications and product development, cybersecurity, data analytics, production and maintenance, hardware/software integration, processing/manufacturing and knowledge of new materials.

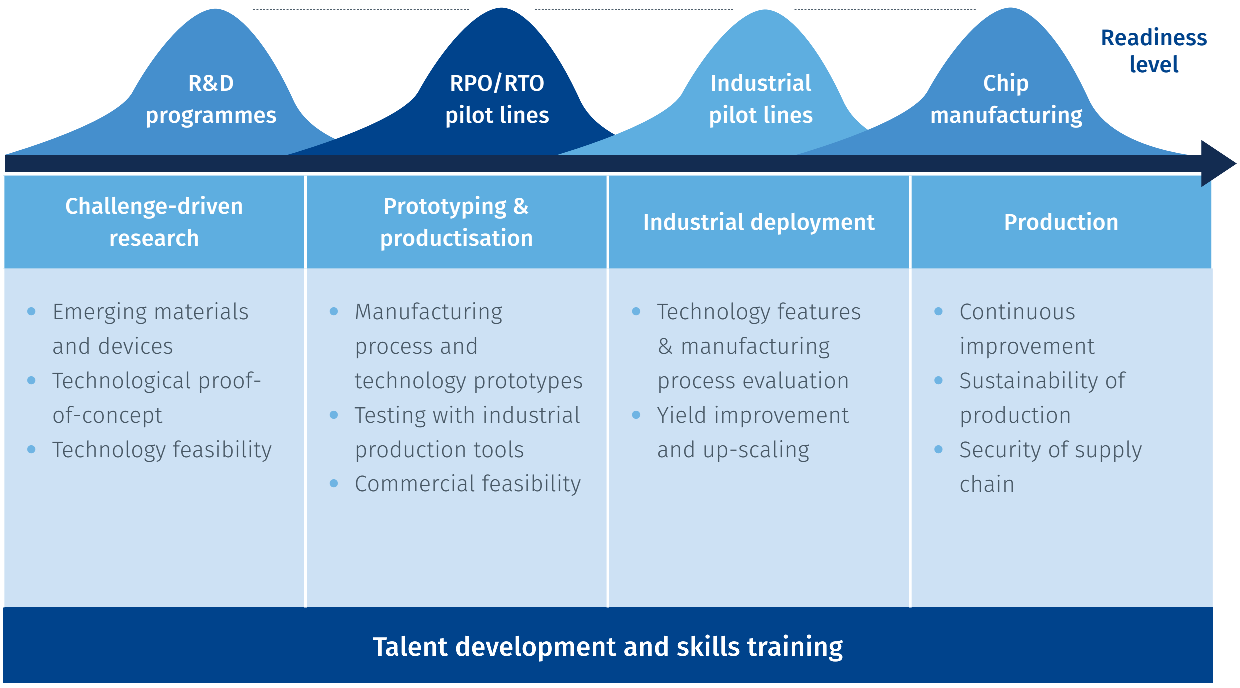


Figure 6: Semiconductor manufacturing pipeline from technology concept to industrial production. This process is capital intensive and typically takes more than ten years of development.

28 Microelectronic Commons – DoD Research & Engineering, OUSD(R&E) (cto.mil)
29 The National Semiconductor Technology Center Update to the Community | NIST
30 Europe's Semiconductor Talent Gap Widens (eetimes.eu; Jan. 2023)

At Tyndall, we aim to

- Deliver semiconductor enabling technologies and building blocks from atoms to systems for next-generation and future electronic and photonic products, and for emerging technology innovations such as edge-AI and quantum chips;
- Offer access to deep-tech expertise, design know-how, state-of-the-art facilities and rapid prototyping for SMEs to catalyse the creation and scale-up of deep-tech Irish start-ups across the semiconductor value chain and the application of semiconductor products;
- Provide leadership as Ireland's semiconductor Centre of Excellence, and catalyse national and international partnerships to drive the growth of the semiconductor business in Ireland and Europe's manufacturing capacity;
- Develop talent for future leaders of the semiconductor industry, establish a high-throughput node for skills development of high-quality engineers, and provide specialised training to industry partners;
- Establish pilot lines for heterogeneous integration and packaging including an open-access MPW[31] service for semiconductor chiplet integration, and provide access to research infrastructure and pilot lines for technology and commercial feasibility.

These undertakings are summarised below under the headings of research and innovation excellence, thought leadership at the national and international levels, pipeline of talent, and unique high-value infrastructure in Ireland.

R&D activities

Semiconductor manufacturing or 'manufacture of computer, electronic and optical products' refer to a broad range of technologies involving multiple material systems, processes and devices performing various functions. There is continuous demand for next-generation and future components for the underlying core technologies of logic and memory for data processing. Known broadly as Moore's Law, this requires the advancement of manufacturing processes at the nanoscale and integration of new materials into devices. Other technologies provide functional diversification through signal processing, power and communication chips, and sensor and actuator systems.

Tyndall leads process development at the atomic scale using Atomic Layer Deposition (ALD), Atomic Layer Etching (ALE) and metallorganic vapour phase epitaxy (MOVPE), e.g., producing the world's most reproducible semiconductor quantum dots for quantum technologies. This is augmented by atomic and molecular-level modelling of semiconductor materials and their deposition, and by defect metrology at semiconductor MOS systems. This research applies to improving device performance and new processes for integration of novel dielectrics and magnetic materials, and for the deposition of metal interconnects in advanced technology nodes.

Tyndall accelerates innovation pathfinding for alternative materials and emerging computing paradigms. Research focuses on device processing, process development and characterisation of 2D van der Waals materials, multiferroics and semiconductor oxides along with the key themes of surface functionalisation and interface engineering at small dimensions. Together with our nanofabrication capabilities, these materials form enabling building blocks for neuromorphic and quantum chips.

While these nanoscale technologies are fundamental for data processing, they are complemented by power electronics and storage technologies, electronic and photonic sensors, mixed-signal processing circuits, radio-frequency (RF) and optical communication devices. These More-than-Moore technologies rely further on materials science and capabilities in system design, assembly and packaging, jointly referred as heterogeneous integration.

Tyndall pioneers the design and implementation of ultralow-power-management integrated circuits for microprocessors in Internet of Things (IoT) devices including mobile phones, and delivers high-impact

31 MPW: Multi-project wafer

design research for the semiconductor industry in mixed-signal, analogue and RF circuits. We also lead advances in a range of sensor platforms – optical, electrochemical, piezoelectric and electromagnetic – for targeted applications in the healthcare, medical technologies, energy and environment, and agriculture sectors.

Tyndall can support the strengthening of Europe's and Ireland's technological capabilities in next-generation chips and integrated device production technologies to take advantage of the benefits that other integrated materials provide for power management and light generation and sensing, e.g., magnetics-on-silicon, Silicon Carbide (SiC) and Gallium Nitride (GaN). Essential technologies here include 3D heterogeneous systems integration at chip scale, and advanced packaging to integrate chips into sub-systems or full systems. This includes the associated production technologies to enable first to manufacture, rapid production scaling and cost minimisation.

Innovation excellence

Tyndall's excellent track-record on innovation builds on transferring technology to Fab & App via licensing to industry and proactively pursuing measures for spin-ins/spin-outs. Enlarging on the successful spin-out of seven semiconductor companies – all of which continue to expand their footprint in Europe through scaling and acquisition – Tyndall is committed to accelerating the digital transformation of European SMEs and catalysing their contribution to economic growth and societal challenges. Tyndall is leading an Irish consortium for a European Digital Innovation Hub which encompasses supports to find investment (as well as test before invest, skill and training, and networking services). This adds to Tyndall's New Ventures programme, hosting of ESA BIC Ireland and the Explorer Deep-Tech Pre Accelerator Programme. Tyndall also partners in the Silicon Catalyst ecosystem, the only global incubator dedicated to semiconductor solutions. The 'Chips Fund' will be a significant additional tool as major investments are required to ensure that Irish and EU semiconductor start-ups are supported throughout scaling-up.

On the partnership side, we are working with all the major global equipment vendors on developing new tool capabilities for wafer fabrication. We are also developing metrology processes complemented by nanoscale device forensics. In 2017, Tyndall entered a long-term collaborative research partnership with ADI across the materials, process and device domains, one of only three global strategic deals for the company, including MIT in the USA and imec in Belgium. The ADI–Tyndall relationship dates back to the early Tyndall–NMRC days when ADI Manufacturing Team members were trained in four-week blocks in theory and hands-on processing in the silicon fab. Many graduates and engineers from Tyndall would have gone to ADI – including Denis Doyle, ex-Head of ADI at Limerick and newly appointed Chair of the Tyndall Board.

Similarly, Tyndall has a long-term partnership with Intel. In Intel's words: "Tyndall has been one of Intel's global research partners for 16 years, conducting fundamental research into advanced semiconductor materials and structures, providing interesting and useful insights to enable informed decisions regarding the future of semiconductor technology. Tyndall has received three Intel Global Outstanding Researcher Awards across 40 research engagements, confirming its position in Irish and European semiconductor research."

Overall, Tyndall offers its services for the uptake of advanced micro/nanoelectronics and photonics technologies, the use of state-of-the-art infrastructure, and expertise in deep-tech to help industry in feasibility studies, prototyping, proof-of-concept demos and research translation to innovation. Over 200 MNCs and SMEs avail of Tyndall's services each year including access to testing and other technical services provided through the unique laboratory and fabrication facilities available.

Thought leadership

Tyndall drives horizon scanning, technology foresight and strategic road mapping on key digital technologies and their enablers, and on emerging topics such as quantum and neuromorphic chips, respectively, for computing and communication and edge-AI. We actively engage in national and EC consultations and in semiconductor research and industry groups. Tyndall is a major contributor to the IEEE International Roadmap for

Devices and Systems (IRDS), the IEEE Heterogeneous Integration Roadmap and the Electronics Components and Systems Strategic Research and Innovation Agenda (ECS-SRIA). The latter underpins the European Partnership on Key Digital Technologies – to be succeeded by the Chips JU – and describes major challenges for semiconductor industrial value chains in Europe.

Tyndall, as a government-funded organisation, is ready to act on behalf of the Government to bring Irish-based stakeholders together across the whole value chain, with the aim of setting up Integrated Production Facilities and an Open EU Foundry – in Ireland or with strong Irish participation – as part of the Security of Supply pillar of the EU Chips Act. Tyndall, together with the government agencies (IDA, EI), could steer an Irish Semiconductor High-Level Group as well as hosting focused events on large-scale investments in chip manufacturing.

Tyndall has already been involved in discussions with Irish and European industry partners to identify opportunities for involvement with Important Projects of Common European Interest (IPCEI) in micro/nanoelectronics. While there is limited scope for direct participation as an RPO, Tyndall can provide research and training supports and work with our network to increase the global footprint of the Irish semiconductor industry. In this context, we have recently embarked on an ambitious project, ICOS, in the framework of international cooperation for the European strategy on semiconductors.[32] Building on an exhaustive analysis of the value chains of semiconductors for electronics and photonics and next-generation and emerging technologies in advanced computation and functionalities, ICOS will target cooperation modalities with leaders in the sector worldwide.

Pipeline of talent

Tyndall trains 160 postgraduate students (MSc, PhD) each year with 60% moving directly to industry, exceeding the average across Irish Higher Education Institutes of approx. 35%. Around 60% of these remain in Ireland and 40% relocate to Europe. Our postdoctoral positions are mostly filled by individuals from outside Europe. The impact of this is that Tyndall is not only training the highest calibre students from across Ireland for technology leadership roles in industry, but also augmenting this talent pool in Ireland with individuals trained at undergraduate, Masters or PhD level at the best universities outside Europe. Two central elements to growing the number of trainees in recent years are the PIADS[33] Centre for Doctoral Training in partnership with Queen's University and the University of Glasgow, and the MSCA COFUND SPARKLE,[34] EDGE[35] and SMART 4.0[36] fellowship training programmes. Collectively these train an additional 120 highly skilled researchers.

Tyndall also provides specialised training to industry partners. A number of short courses are targeted at supporting technician-level grades including those seeking to upskill from other sectors, e.g., we have upskilled ADI engineers in CMOS processing through our training fab. Here, the presence of our training fab and packaging facilities (one of a very limited number across Europe) is instrumental as it enables hands-on training, while we also take a European leadership role. In Tyndall, we lead hands-on training across Europe in packaging and system integration. We currently spearhead the European Photonics Academy, a trans-Europe platform composed of 40 training centres, where we expect to support 6,000 European companies with training over the next four years.

32 ICOS 'International Cooperation on Semiconductors' was officially launched on January 19, 2023 in Brussels
33 Centre for Doctoral Training (CDT) in Photonic Integration and Advanced Data Storage (PIADS) is a partnership between the Irish Photonic Integration Centre (IPIC), Queen's University Belfast and University of Glasgow
34 Sparkle MSCA COFUND
35 Edge Research MSCA COFUND
36 Smart 4.0 MSCA COFUND

High-capital infrastructure and pilot lines

A 750m² ISO7/ISO5 (litho) 'FlexiFab' allows for agile wafer-scale nanofabrication and processing beyond silicon, and for experimenting with the integration of selected new materials and architectures aimed at enhanced device performance and added functionality. This agility enabled Tyndall to lead ASCENT+, a €10m EU-funded programme that offers a direct single-entry point to key European infrastructures including imec, CEA-leti, Fraunhofer Mikroelektronik and INL.[37]

Utilising both the FlexiFab and our 250m² ISO6/ISO4 (litho) CMOS-compatible cleanroom ('CleanFab') – the only non-commercial such facility in Ireland – we innovate the development of building blocks for more advanced nodes and future computing architectures such as neuromorphic, quantum and optical. Examples include the junctionless transistor – licensed to the largest semiconductor foundry and the largest semiconductor chip manufacturer in the world, back-end-of-the-line functionality, quantum and synaptic devices, optical components and waveguides, and integration of magnetics-on-silicon for power supply on a chip.

Tyndall is a European leader in hybrid integration of heterogeneous semiconductor chips for rapid (sub-) system prototyping, offering pilot lines for heterogeneous chiplet integration and packaging (flipchip single chiplet and design rules) and micro-transfer printing (mass chiplet transfer). For example, Tyndall leads the EU-funded photonics packaging pilot-line PIXAPP[38] and the EnABLES infrastructure[39] aimed at system integration to power the IoT.

Tyndall has established physical pilot lines that not only develop the required technologies but also simultaneously advance the production tools to enable the fabrication of the products. Initially tools located in Tyndall can be used for low-volume production runs, which can then be installed in the industry partners' sites as production volumes scale. The benefit of these pilot lines has been immeasurable, in particular to end-user companies and SMEs, which may have low existing capability or infrastructure in chip integration and packaging, or in the case of SMEs, may not have the resources to invest upfront, or at least until the technology is proven. Such pilot lines also bring the advantage of enabling the formation of new vertical supply chains, which is hugely beneficial as the industrial landscape can often be fragmented or disjointed. Tyndall can efficiently and rapidly form such new vertical supply chains, build pilot lines, and enable open access to industry partners, as they see the value and seek to benefit from it.

Overall, more than €100m has been invested in the Tyndall infrastructure since 2004, and further investment is foreseen under the Irish Government's National Development Plan (NDP) 2018–2027. By 2025, we will add another 16,000m² of labs and offices to expand our activities, doubling our footprint and impact.

37 ASCENT+ – European Nanoelectronics Network
38 PIXAPP – Photonics Packaging Pilot Line
39 EnABLES – European Infrastructure Powering the Internet of Things

Case one – MagIC: making magnetic components disappear for sustainable energy-efficient electronics

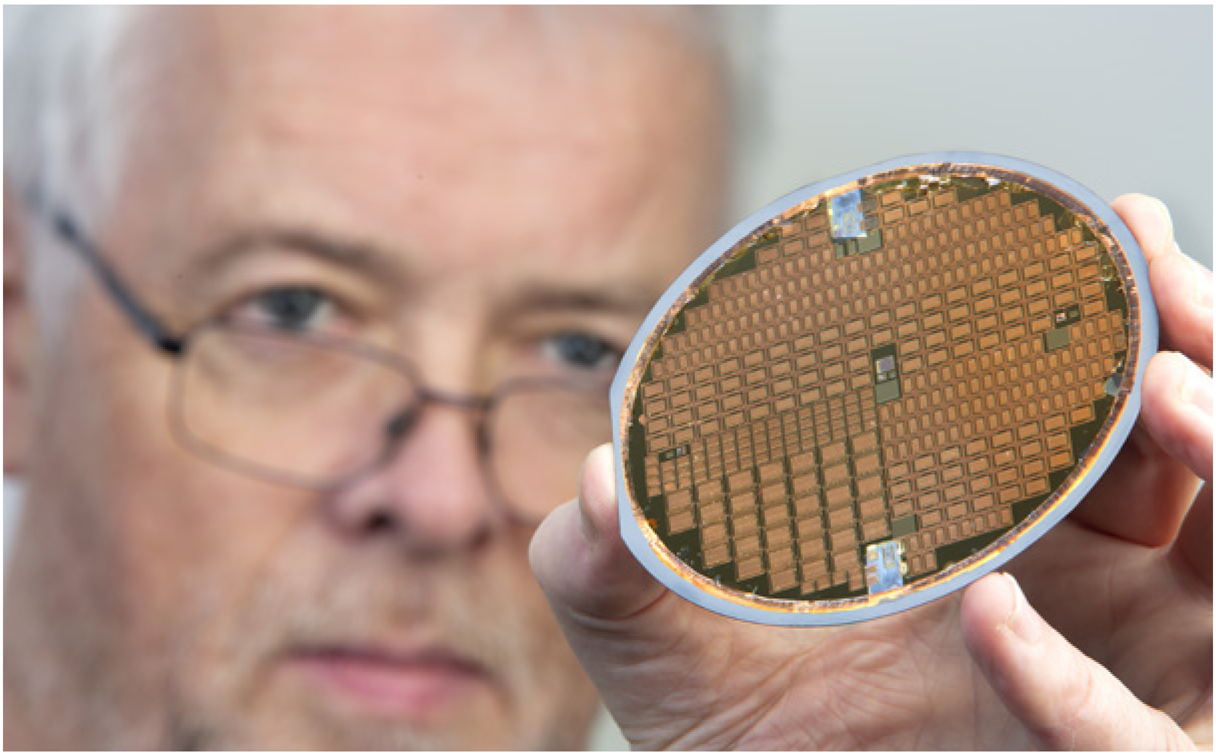
A major roadblock to minimising energy consumption in electronics (from smartphones to data-centre servers) has been the inability to miniaturise and integrate power supply circuits into microprocessor chips due to bulky magnetic inductors in the off-chip, dc-dc converters used to deliver power to the system circuits.

For more than a decade, Tyndall has supported the investment of more than 200 person years in the MagIC programme and in the Integrated Magnetics Group, enabling the programme to become recognised as world-leading and the group to be acknowledged as global thought-leaders in this highly disruptive, emerging space.

The MagIC platform comprises:

- magnetics (inductors) from 1 to 100 nanoHenries, Q-factor above 25, 100MHz operation and beyond, footprint less than 1mm², height below 100microns
- validated design/simulation tools
- process flows and design rules for high-volume fabrication
- material specifications for laminated, thin-film magnetic cores
- magnetic material characterisation protocols and inductor test methodologies.

While most of MagIC's client engagements are confidential under NDA, we can say that the MagIC platform is licensed to two global smartphone brands and a leading semiconductor foundry. Tyndall also supports a significant number of supply chain partners ensuring a viable supply chain is in place to accelerate adoption. The team has had funded collaborations with more than 16 world-leading companies and co-authored journal and conference publications with many institutes and European companies including AT&S, Bosch, Global Foundries, IBM, Infineon, MuRata/IPDiA, Tridonic, Wurth Electronics as well as Intel and TI in the USA. In 2019, the team had a joint patent granted with Apple.



Case two – InfiniLED: microLED display technology spin-out advancing the metaverse

Screen displays are ubiquitous, from smartphones, tablets and laptops to VR headsets, AR and digital screen displays, and TV/PC monitors. They are also energy drains for the battery life of mobile devices and our overall electricity consumption. The larger the display and the sharper the image, the more power consuming they are. MicroLEDs is a next-generation light source technology which delivers light efficiently and accurately into miniature applications.

MicroLED technology has been developed for more than 10 years at Tyndall. The patented MicroLED platform was licensed to the InfiniLED spin-out in 2011. Pioneering the design and manufacture of modules incorporating MicroLEDs, optical components and advanced photonics packaging, InfiniLED was subsequently acquired by Meta-owned Oculus to enhance the performance of its VR devices. Meta now employs over 100 people in the advanced AR/VR research team in their Reality Labs based in Cork.

Case three – SAFE: end-to-end sensor systems for the digital transformation of the agrifood industry

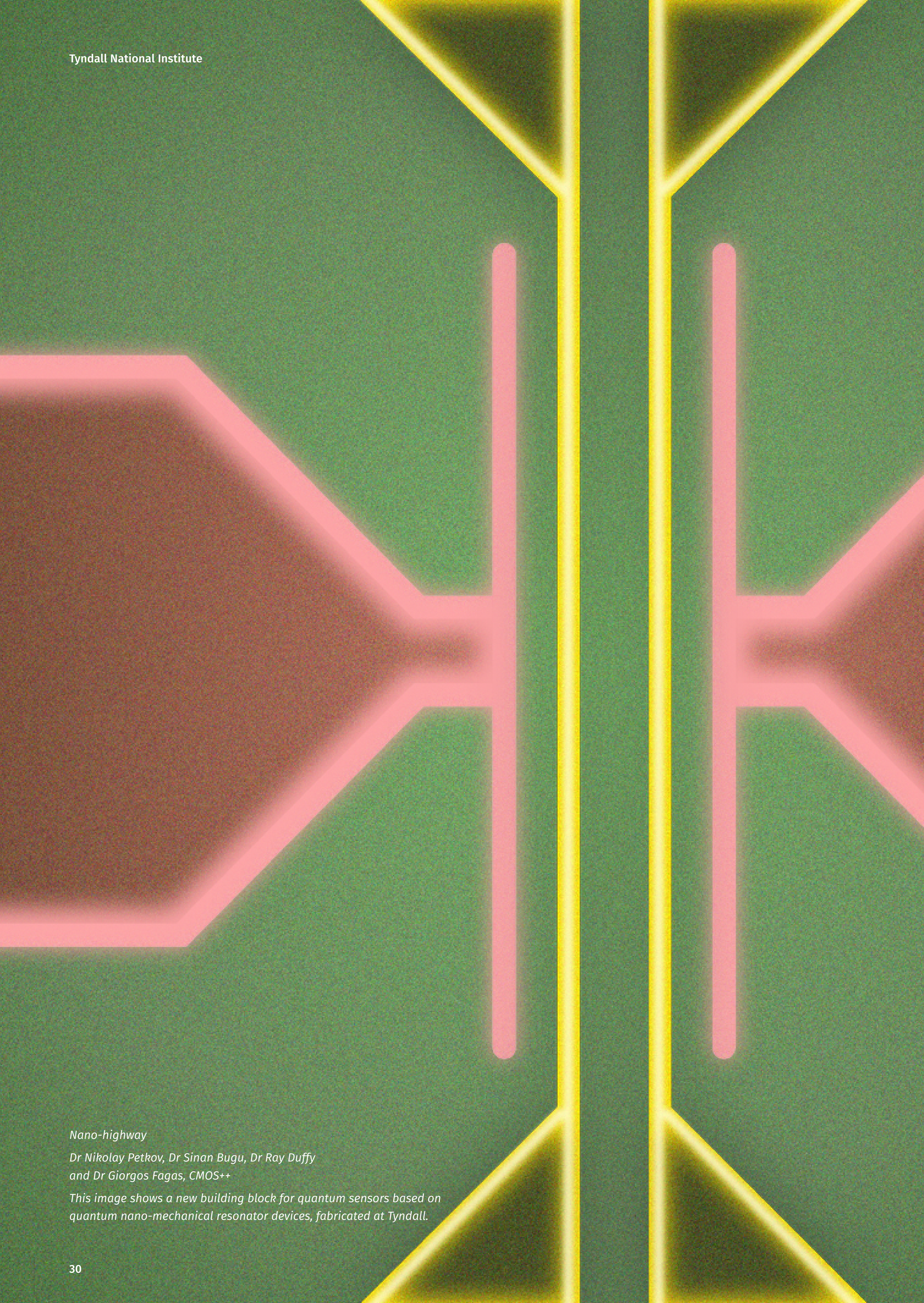
Global food production needs to increase in order to meet the demands of an ever-growing global population. Digital technologies have the potential to revolutionise the whole agrifood and environment supply chain and will play a significant role in transforming the traditional agriculture industry to a knowledge-based one. The increased connectivity of a global agriculture would enable producers to use their data to apply the 4R farm management strategy (Right product, Right place, Right time, Right rate). While processors could employ data to reduce losses, maximise production, increase quality, and address consumer concerns, e.g., traceability. To enable this paradigm shift, new decision support tools and advanced analytics based on embedded and connected point-of-use sensors and systems are required to yield (quasi)real-time data that will provide informed decision making capacity to stakeholders.

One exemplar of such a system is the development of a soil nutrient sensor system by the Sustainable Agrifood and the Environment (SAFE) Strategic Research Cluster at Tyndall, co-developed with the EU H2020 project Sarmenti and the Science Foundation Ireland Research Centre Vistamilk.

The system has been deployed buried in soil for three months on farms across Europe and comprises:

- Multiple sensors for simultaneous detection of nitrate, nitrite, pH, dissolved oxygen and phosphate
- An electrochemical on-chip approach to tailor the pH of the soil moisture thereby eliminating the need for addition of chemical reagents, i.e. acids
- A stabilised reference electrode, thereby eliminating a key bottleneck to prolonged deployments
- Full connectivity to the cloud using LoRa communications.

The team collaborates nationally with Teagasc and internationally with key stakeholders, employing a multi-actor co-design approach, to ensure that developed technologies are fit for purpose. The technology is patent pending and builds on an existing patent portfolio. The process of incorporating a start-up company to translate this ground-breaking research to the marketplace has begun.



Nano-highway

Dr Nikolay Petkov, Dr Sinan Bugu, Dr Ray Duffy and Dr Giorgos Fagas, CMOS++

This image shows a new building block for quantum sensors based on quantum nano-mechanical resonator devices, fabricated at Tyndall.

About the author

Dr Giorgos Fagas

Dr Giorgos Fagas MBA is the Head of the CMOS++ Research Cluster at Tyndall, a strategic programme addressing emerging materials, devices and architectures for next-generation information processing interfacing with CMOS and beyond. Dr Fagas is also Head of EU Programmes and a member of Tyndall's Institutional Leadership Team.

Dr Fagas has been an active promoter of research and innovation with his contributions to national and international strategic agendas. He holds prominent positions in various research policy and industry innovation groups. Dr Fagas is Director of the SiNANO European Academic and Scientific Association for Nanoelectronics, the Scientific Council of the AENEAS Industry Association for European Nanoelectronics Activities, and the executive committee of the EPoSS European Platform on Smart Systems Integration. He also currently holds the Europe Chair in the MIDAS Industry Association for Microelectronics and Electronic Systems Design in Ireland.

Dr Fagas leads the Quantum Electronic Devices group. He has been a principal investigator in 13 EU projects (coordinating two of these), three SFI PI and one Frontiers for Partnership Awards, and several Enterprise Ireland Grants. He has also instigated a dozen others, including the first multi-partner multi-million investment in quantum computing in Ireland. Dr Fagas currently leads the EU-funded programme of ASCENT+ Access to European Infrastructure in Nanoelectronics. His research has been published in over 70 peer-reviewed articles; he is also editor of one reference book on molecular electronics and two books on ICT-energy concepts.

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European Union
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