Imperial College London

Response to Industrial Strategy Green Paper

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Summary

1. Imperial College London's mission is to achieve enduring excellence in research and education in science, engineering, medicine and business for the benefit of society.

2. Imperial generates world-class talent and research that drives productivity and growth across the UK. Investing in high-level skills for a broader cross-section of our own population and welcoming the best talent from across the world into the UK will supply our science, research and innovation pipeline for years to come.

3. The ability to collaborate across borders with people from different backgrounds, cultures and nationalities is what drives the world's best universities. We need continued access to EU programmes and collaboration and our immigration system needs to attract the best and brightest students, academics and entrepreneurs.

Build on our strengths and extend excellence into the future

4. Extending excellence at global top ten universities like Imperial[1] requires sustained and balanced investment across the whole research spectrum from fundamental discovery to applied research. The Industrial Strategy should support a globally competitive UK economy by providing a roadmap to spend 3% of GDP on R&D investment in line with our international counterparts.

5. As the UK's foremost science and technology university Imperial recognises its role in reaching out and inspiring young people to take up STEM subjects. We are committed to producing the highly skilled STEM graduates with the entrepreneurial and technical skills that industry demands. Government can support this work through sustainable funding for STEM disciplines.

Close the gap between the UK's most productive companies, industries, places and people and the rest

6. Imperial collaborates with research partners across the UK to tackle global challenges for the benefit of all society. As a global university in a global city Imperial uses London's scale and capacity to accelerate discovery into a vibrant and competitive science and innovation ecosystem providing an important source of translation for the UK as a whole.

7. Support for successful university clusters will accelerate close working with major corporates, start-ups and scale-ups and other partners. Our White City Campus is a new research and innovation district where researchers will co-locate and collaborate with industry and research partners to develop the next generation of advanced technologies. Our innovation spaces are open to both the Imperial community and the public to develop new skills, foster an understanding of 'making and manufacture', and inspire and encourage the next generation of inventors.

Make the UK one of the most competitive places in the world to start or grow a business

8. Investing in innovation at universities supports the commercialisation of ideas and creates an institutional culture that embraces discovery and entrepreneurship. Increasing investment through HEIF; implementing tax reform to incentivise university-business collaboration and co-location, and maintaining autonomy over managing intellectual property and technology transfer are all practical ways to achieve this through the Industrial Strategy.

9. Please note that in addition to this Imperial College London response, there will be other responses from specific areas of the College's academic community.

[1] *World University Rankings,* Times Higher Education (2017)

Investing in science, research and innovation

10. The dual support system for funding underpins our world-class research base. We welcome the additional £4.7 billion investment in R&D[2] and the legislative protection for the Haldane Principle in the Higher Education and Research Bill.

11. The ISGP recognises the UK science base as the most productive of the G7 countries.[3] There is clear evidence that **publicly funded R&D creates a strong 'multiplier effect' and 'crowds-in' private sector, charitable and inward investment**, stimulating around 30% more self-investment from industry.[4] Building a pipeline of discovery will support future productivity and growth and the Government should develop **a roadmap for increasing R&D investment to 3% of GDP** in line with our international counterparts.[5]

12. This increased investment would strengthen the research base as the Government negotiates continued access to **European Research programmes**.[6] Imperial currently has 198 participants in Horizon 2020, receiving a total of €128 million of funding – **the 4th highest of all EU HEIs**. European Research Council grants have supported research into nanomaterials and tissue engineering[7]; the development of the AcuPebble, a wearable wireless diagnostic tool for a range of illnesses[8]; and the European AIDS Vaccine Initiative led by Imperial.[9]

    - We urge the Government to **secure continued access to European programmes supporting excellent research** as part of the negotiation of a future relationship with the EU.

Fundamental research

13. Investment in science, research and innovation needs to be **balanced across the research ecosystem** from fundamental discovery to applied research. Fundamental research at Imperial has led to unanticipated breakthroughs, in some cases after a significant time period had passed. For example one of the world's leading theoretical physicists Professor Sir John Pendry pursued **fundamental research which led to the development of metamaterials** that can create perfect lenses and cloak objects.[10] Professor Steve Bloom's **revolutionary advances in appetite reduction therapies** came from a breakthrough understanding of how gut hormones act as neurotransmitters some **thirty years after initial discoveries**. His research has been brought to society through two spin out companies and is now working on an EU-funded project on a microchip to recognise and process signatures of appetite, mimic instructions to the brain and reduce the urge to eat.[11]

14. Our international competitors recognise the many benefits of a strong foundation of fundamental research to making the discoveries that lead to truly new innovations. The **Chinese Government has increased spending on fundamental research** in response to concerns that their historic weakness in this area has hindered innovation.[12]

15. Imperial's **Excellence Fund for Frontier Research** is one example of how we support a culture that embraces discovery. The fund has supported breakthroughs already, such as adapting technology used by the oil and gas industry to search for new fossil fuel reserves, to be used in medical imaging.[13]

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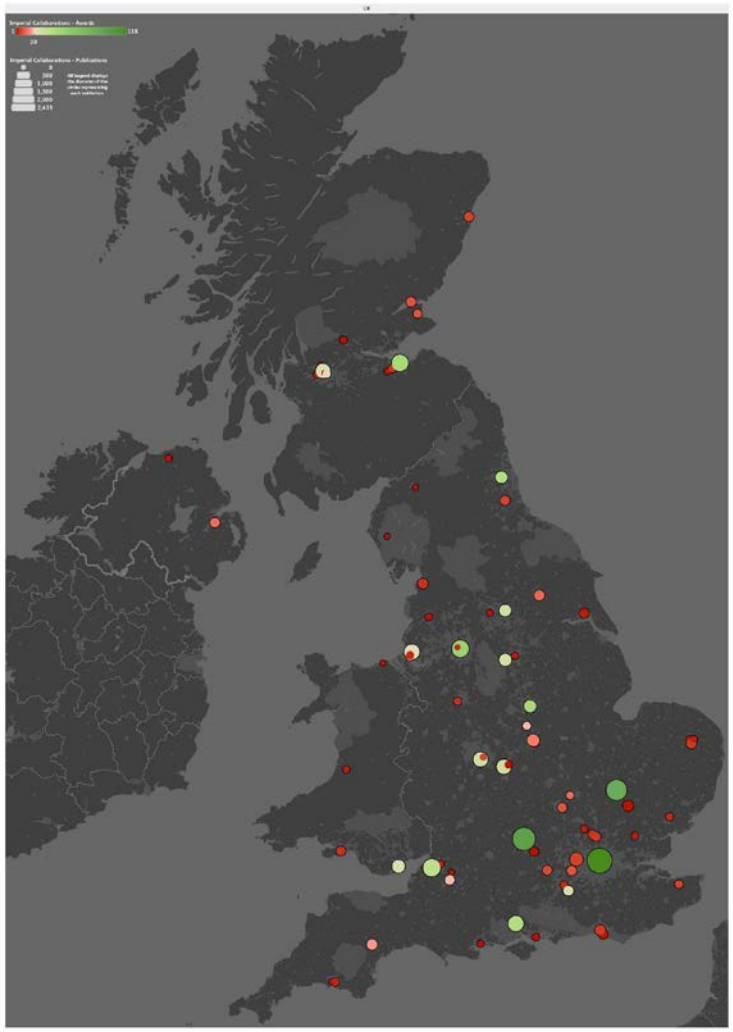
[2] *Funding for Higher Education in England for 2017-18: HEFCE grant letter*, DfE (February 2017)
[3] *International Comparative Performance of the UK Research Base*, Elsevier (2013)
[4] *The Economic Significance of the UK Science Base,* Haskel, Hughes and Bascavusoglu-Moreau (March 2014)
[5] *Now is the time to innovate: the road to three percent,* CBI (March 2017)
[6] *UK's participation in Horizon 2020*, BEIS (February 2017)
[7] See *Nanotechnology to help rebuild bodies and detect disease*, ERC (January 2013);
[8] See www.imperial.ac.uk/people/e.rodriguez/research.html
[9] See HIV scientists launch 23 million euro project to develop vaccine, Horizon 2020 (October 2015)
[10] See Imperial physicist shares $1M Kavli Prize for perfect lens (May 2015)
[11] See Hormone combination reduces appetite (March 2013)
[12] *Nature* (March 2014)
[13] See Future game-changers win backing from Excellence Fund (March 2017)

Research excellence and impact

16. To maximise impact, investment in R&D should be driven by excellence.[14] Imperial is one of the world's top universities with the greatest concentration of high-impact research of any major UK university.[15] This focus on impact – the benefit that research has on society – drives our researchers to build bridges across disciplines and tackle the most challenging problems of the future. The **Antimicrobial Research Collaborative** expands interdisciplinary collaborations across the Faculties of Natural Sciences, Medicine, Engineering and the Imperial College Business School; the Imperial College Healthcare NHS Trust and a broad range of academic, industrial and third party collaborators.

17. Investment in research at Imperial drives high quality scientific output that reaches way beyond our campus boundaries and **supports valuable collaborations with research partners across the UK for the benefit of society as a whole** (refer Fig 1). From 2013-2016 Imperial shared research grants with 114 UK institutions and from 2013-2015 Imperial co-authored publications with over 500 UK organisations.

    Fig 1: Map showing concentration of Imperial collaborations with partners across the UK with whom one or more awards have been shared



[14] As Professor Graeme Reid, previously head of research funding in BIS, argues *"…strong science is sustained by meritocratic allocation of resources based on peer review…"* National Centre for Universities and Business
[15] See Imperial has UK's greatest research impact, finds REF 2014 (December 2014)

18. Translating excellent research is also dependent on the ability of industry to identify and use the knowledge produced. **London's scale and capacity to accelerate discovery into a vibrant and competitive science and innovation ecosystem provides an important source of translation for the UK.** The concentration of high-quality research at universities like Imperial and a thriving business culture drives productivity and growth right across the UK.

Bringing together sectors and places

19. Universities support innovation in multiple ways including: attracting young skilled people; spinning out new companies based on new technologies and services; and attracting research-intensive businesses to locate in the area.

    - Government should **support successful university clusters** to accelerate their work with major corporates, start-ups and scale-ups and other partners.

20. Our **White City Campus is a new research and innovation district** in the heart of West London where a diverse community of researchers are co-locating and collaborating with major corporates, start-ups and scale-ups, entrepreneurs and research partners to develop the next generation of advanced technologies.[16]

21. We are already developing collaborative research facilities for molecular sciences and biomedical engineering along with a new Transformation and Innovation Hub (I-HUB) opened in 2016. For the next phase of development on the 23 acre site we are looking for Government and industry partners to collaborate on building new multidisciplinary hubs and facilities to tackle new global challenges together across sectors. Such unprecedented mixing of partners within buildings and across the campus will keep the UK at the forefront of new technologies. Opportunities include:

    - An **Advanced Technologies Innovation Hub** to develop the next generation Advanced Materials, Robotics, Synthetic Biology, Sustainability and Industrial Biotechnology and Agritech. The UK needs an expansive ambition to stimulate novel technologies to maintain our advantage in each sector. The Hub will serve as a focus for multidisciplinary partnerships and provide key research and translation facilities including additive layer manufacturing to support robotics research, clean rooms for advanced material synthesis and fabrication, wet labs for synthetic biology, and scale-up facilities for chemical processing and industrial biotechnology.
    - A **MedTech Hub** to focus on extreme computing, machine learning and biodata mining and exploration for the benefit of patients and consumers. This is a unique opportunity to work with industry to lead the AI driven revolution in health and medicine. Building on pioneering research in precision healthcare and biomedical engineering we can create a broader ecosystem of top researchers and practitioners, business and the public sector close to our existing centre for innovative research at Hammersmith Hospital.
    - A **CleanTech Institute** to convene technologists, scientists, architects, business and planners to conceive, build and test the sustainable technologies that will support society into the future. This would also support the creation of a Clean Tech cluster in West London, and act as a catalyst for regeneration by attracting clean tech start-ups and businesses to the area.

22. The ISGP recognizes the **potential of universities to attract R&D investment to the UK**. This is in no small part due to existing UK clusters of ideas, talent and capital. By bringing together inventors, entrepreneurs, investors, academics and creatives on a grand scale, our enterprise and technology capabilities allow us to compete with major centres such as San Francisco, Boston and South East Asia. The UK must capitalise on these clusters to ensure we remain globally competitive.

[16] Our research priorities are based around four themes: discovery and the natural world; engineering novel solutions; health and well-being; and leading the data revolution.

Priorities for investment in science, research and innovation

23. We welcome the continuity of the **Industrial Strategy Challenge Fund** priority areas with the previous Eight Great Technologies strategy.

    - We believe **Sustainable Cities**[17] and **Creative Industries**[18] should be included based on the criteria outlined in the IGSP.

24. Complex societal challenges require multidisciplinary approaches and investment mechanisms must be responsive to innovative proposals, which cut across the boundaries of the research areas identified in the ISGP. Our **Global Challenge Institutes** bring together academic talent from a range of disciplines to collaborate with policy-makers and business to apply new knowledge and provide scientific advice.[19]

25. The UK has complementary strengths in institutions across the country, and our universities have excellent track records of collaboration on complex multidisciplinary problems.

    - We support the ISGP aim for the UK to be global leader in battery technology. We believe a **distributed research institute for battery technology** would bring leading teams in academia together, in partnership with industry. We prefer a hub and spoke model or virtual institute based at HEIs to avoid duplication of existing facilities and expertise.

Supporting and developing research talent

26. The UK's **world-class research base is dependent on a pipeline of highly skilled world-class research talent**. Imperial must be able to continue developing home grown talent, while also recruiting and retaining the very best researchers from around the world who enhance the quality of existing research as well as opening up unexplored areas.

27. The Spring Budget announcements to increase the number of STEM PhD places, invest in new fellowships for early and mid-career researchers in areas aligned to the Industrial Strategy and support for global research talent are welcome. [20] They should form part of a strategy to support academic career paths to ensure highly skilled researchers are developed and retained in the UK.

    - Investing some of the **Apprenticeship Levy** in support for early career academics could strengthen their training and career development.

28. The ability to **collaborate across borders with people from different backgrounds, cultures and nationalities drives the world's best universities**. The ISGP echoes the Prime Minister's commitment to maintain collaboration with European partners on major science, research and technology initiatives.[21] Imperial collaborations include **Europe-wide projects to tackle meningitis, dementia and cancer** and the development of **next generation electronics**. In Autumn 2016 Imperial launched a **European Partners Fund** to help seed and develop new collaborations with European colleagues.

29. Imperial's 2,000 **staff from other European counties are vital for our ongoing teaching and research excellence**. Hungarian researcher, Professor Zoltán Takáts, developed the iKnife at Imperial, a scalpel that tells surgeons immediately whether the tissue they are cutting is cancerous or not, transforming surgery and saving lives.

[17] The UK is internationally leading in many research areas relating to Sustainable Urban Environments and has strong links with industry.
[18] The UK is internationally leading in Creative Industries, including Design Engineering which is the fusion of design thinking, and engineering knowledge and practice within a culture of innovation and enterprise.
[19] Grantham Institute – Climate Change and Environment; Institute of Global Health Innovation; Energy Futures Lab; Institute for Security Science and Technology; Data Science Institute; Institute for Molecular Science and Engineering
[20] Spring Budget, HM Treasury (March 2017)
[21] Prime Minister's Commons statement on triggering Article 50 (March 2017)

- **EU citizens must be able to remain in Britain** and the Government should take a proactive position to ensure Europeans who live here today are welcome to stay.[22]
- In future we support **linking scientific mobility with research funding** where participants in EU-funded research projects automatically receive a visa for free movement between Britain and the EU.[23]

30. Imperial is the UK's most international university and it is vital that we continue to attract top international talent to support the industrial strategy and enhance the UK's position as a world leader in science, innovation and higher education.[24] We advocate **a range of visa reforms that are targeted at the best and brightest students, academics and entrepreneurs**:

    - Easing the Tier 1 visa route for workers with exceptional talent such as top researchers
    - Expanding the Doctorate Extension Scheme for STEM PhD students from one year to three years to match recent US reforms targeted at STEM PhDs
    - Expanding Tier 1 graduate entrepreneur visas to encourage the brightest foreign students to develop their business ideas and create jobs
    - Expand the Tier 4 pilot scheme for Masters students to cover undergraduate and PhD students at highly trusted institutions
    - Introduce a new post-study work visa for top STEM graduates

Creating an environment to support the commercialisation of research

31. During the last decade revenues to UK universities from licensing and the sale of spin-out companies have more than doubled and the investment in intellectual property by universities has risen by a third.[25] **Imperial ranks highly in terms of commercialising intellectual property and entrepreneurship**.[26] In an average year, our Technology Transfer Office (TTO) (provided by Imperial Innovations) assesses around 400 inventions disclosed by Imperial staff, completes 30-40 licence deals, forms eight new companies and files patents on 60 new technologies.[27]

32. Universities need to **maintain their autonomy to manage their own intellectual property**. There is no 'one size fits all' approach to university technology transfer. What works for a regionally focused, teaching intensive university may not work for a globally focused, research-intensive institution. Equally, the approach needed to get a therapeutic drug to market is very different from that required to bootstrap a fast-moving small software business to market.

33. We look forward to **engaging in the research the Government plans to commission on best practice for commercialisation and managing intellectual property**. For example we are piloting a scheme at Imperial which gives academics the choice of a founder-driven route with minimal equity stake for the university and a significant equity stake for the academic where the academic progresses the company themselves with reduced support from the TTO.[28] The traditional route will also be available, in which the TTO plays a greater role in the company formation and development. The academic will have a choice which route to adopt.

    - We support the **creation of a proof of concept fund** to support the commercialisation of ideas across the research spectrum. This would address issues raised by an Innovate UK report that found current proof of concept funding is fragmented and not always consistently available.[29]

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[22] See www.imperial.ac.uk/about/leadership-and-strategy/president/writing-and-speeches/presidents-address-2017/
[23] See http://www.economist.com/news/letters/21708986-letters-editor
[24] *The World's Most International Universities*, Times Higher Education (2017)
[25] University Knowledge Exchange (KE) Framework: good practice in technology transfer, HEFCE (August 2016)
[26] A study commissioned by the MIT Skolkovo Institute found that Imperial College London was one of three UK universities ranked alongside MIT and Stanford from the USA in creating entrepreneurial ecosystems, with the other two universities being the University of Cambridge and the University of Oxford. *Creating university-based entrepreneurial ecosystems: evidence from emerging world leaders*, (2014)
[27] Imperial Innovations combines the activities of technology transfer and technology commercialisation and patient capital investment.
[28] The founder-driven route more closely matches the approach taken by MIT and Stanford University
[29] *Review of UK Proof of Concept Support*, IP Pragmatics (September 2015)

34. **Impact Acceleration Accounts (IAAs) provide a more flexible model for universities to interact with industry** than Knowledge Transfer Partnerships (KTPs). IAAs help academics realise the potential of their technologies through spin-outs and licensing, collaborative routes to co-create new technologies with industry, and providing expertise to help solve problems identified by industry. KTPs only realistically offer opportunities within this last category. Essential to an effective technology commercialisation programme is strong university-industry collaboration.

Strengthening university-business collaboration

35. Imperial has **more than 500 corporate partners** with whom we work closely on **collaborative research, applying academic intellect to address fundamental challenges, and developing the next generation of talent to join the companies' workforce**. This takes the form of research consortia like the BP International Centre for Advanced Materials; capital projects like the Dyson School of Engineering; or spin-outs like Permasense, Pulmocide and Topivert. In 2015/16 our **research income from industry was nearly £54m** (over 15% of total research income).

36. **HEIF is very effective in helping universities translate research ideas, knowledge and technology strengths into both economic and social impacts**. The average return on investment across the sector is £9.70 in benefits for the economy and society for every £1 invested, and considerably more when invested in the most research-intensive universities.[30]

    - **Lifting the cap on funding available to individual universities would allow us to build on successful HEIF projects.** For example HEIF funding supported the creation of our Enterprise Lab which encourages and supports student entrepreneurs through an environment which facilitates peer collaboration and mentoring. The Lab is being extended to include post-docs, early career researchers and a team based mentoring programme, building on the MIT Venture Mentoring Service, will launch in 2017/18. Extending this service, to staff for example, would be possible with additional HEIF funding.

37. Some of our most productive university-industry collaborations involve co-location with staff from our corporate partners. The **R&D tax environment could be further reformed to incentivise greater university-business collaboration and co-location**. Uncertainty over liability for VAT on new research facilities and the supply of research services create unnecessary barriers to co-location and collaborations between businesses and universities.

    - A **targeted VAT exemption for new university buildings** used for collaboration with business would remove these disincentives. [31]

Supporting research and innovation strengths in local areas

38. We are opening the doors of our new innovation spaces at White City to the local community. The **Invention Rooms** are dedicated innovation spaces for people of all ages and backgrounds. This is one of the **first projects of its kind in the UK** and will create opportunities for the public to develop new skills and an understanding of 'making and manufacture', thereby encouraging the next generation of inventors at White City.

    - **Reach Out Makerspace** – a workshop and design studio for young people from the local community to be inspired and gain hands-on experience of making and entrepreneurship.
    - **Advanced Hackspace** – an expansion of our hackspace network where the community, alumni and partners access advanced prototyping and fabrication equipment from robotics and digital fabrication to a bio-lab which enables synthetic biology and molecular fabrication.[32]
    - **Interaction Zone** – a venue for public events, where the public and College partners can connect with science and Imperial's research.

[30] *Assessing the Economic Impacts of the Higher Education Innovation Fund: a Mixed-Method Quantitative Assessment* (October 2015)
[31] Commons Science & Technology Committee 'Managing intellectual property and technology transfer' (2017)
[32] The hackspace network includes facilities at the Dyson School of Design Engineering at South Kensington and the National Heart and Lung Institute at Hammersmith Hospital. The new space at the Invention Rooms and the Molecular Sciences Research Hub (under construction at White City) will make Imperial home to one of the largest hackspace networks in the world, covering almost 30,000 sq ft.

39. The Invention Rooms' **hackspace will provide space for users to work alongside SMEs and industry partners to support the commercialisation of their ideas**. Recent inventions to start upscaling include LifeCradle, a baby incubator that is 90 per cent cheaper to produce than current models and the Gyroglove, a wearable device which helps stabilise the hand of patients suffering tremors, such as those caused by Parkinson's disease.

40. Incentivising the development and operation of **small business incubators** is a key part of supporting research and innovation in local areas. Schemes such as reducing or removing business rates completely for incubators would help local areas stimulate growth from start-ups.

Developing Skills

Boosting the STEM skills pipeline

41. We strongly endorse the need to **strengthen the pipeline for STEM skills** to meet the demand from employers. This work needs to reach back into primary and secondary education to continue to increase the proportion of the population who are equipped with the advanced skills required in a leading economy.

42. Imperial is passionate about **inspiring young people to study STEM** subjects and consider STEM careers. Our outreach work begins at primary schools where young people are encouraged to talk about, engage with and participate in science; then there are interactions at key decisions points, such as choosing to study science further at secondary school, or choosing to study STEM subjects at a university like Imperial.[33]

    - The new **Reach Out Maker Space** at White City will motivate and excite young people to get involved in STEM and develop confidence in their abilities through hands-on experience of 'making and manufacture'.
    - **Stem Potential** is a flagship cohort programme for academically capable students in Years 10-13 which provides master-classes, revision classes, soft skills and support for making university applications in STEM subjects. **Pathways to Medicine** is a cohort programme specifically targeting applications to Medical Schools.
    - The **Wohl ReachOut Lab** provides opportunities for students aged 6-18 years old to participate in hands-on STEM learning. Last year over we had over 4000 participants.
    - **ReachOut CPD** is our free online resource for UK primary school teachers to learn about scientific concepts and bring science to life through film, practical activities and experiments. All materials draw on Imperial's expertise in science teaching and research. Over 14000 teachers from over 7000 schools are registered.

Highly skilled graduates

43. Imperial produces **highly skilled STEM graduates** with the strong technical knowledge, creative and entrepreneurial problem solving skills and experience of working in multi-cultural teams that are in high demand by employers in a global economy.[34] Imperial is the UK's foremost science and technology-focused university, ranked third in the UK for Physical Sciences, Engineering and Technology and Life Sciences, and fourth in the UK for Medicine.[35]

44. The provision of **high-quality, research-led STEM education is resource-intensive**, requiring the use of expensive facilities and high cost consumables. Currently these substantially higher costs compared to other disciplines are not sufficiently reflected in the relative subject funding weightings. Lack of sufficient funding for STEM disciplines leads to less choice and diminishing opportunities for students, and to a wider impact on the UK economy where there is already a shortage of suitably qualified STEM graduates.[36]

[33] Written evidence submitted by Imperial College London to the Commons Science and Technology Select Committee 'Science Communication' (April 2016)
[34] 91% of our first degree graduates are in work and\or study 6 months after graduation (average starting salary of £34 000); over 17% of our undergraduate students come from EU countries, and over 30% from outside the EU
[35] *World University Rankings by Subject*, Times Higher Education (2015-16)
[36] For example, *Jobs and growth: the importance of engineering skills to the UK economy*, Royal Academy of Engineering

45. As a research-intensive university, Imperial enjoys access to specialist facilities that would not otherwise be available. The College is able to use its (often research-led) relationships with industry to provide access to facilities such as the **Chemical Engineering Discovery Space**, which closely mimic real-world conditions. We can provide these opportunities for directed and independent learning because the College undertakes educational activities in a research context.

46. The College has extensive links with industry, and these are leveraged in order to provide our students with enhanced learning experiences. Many **departments have formal industrial liaison groups**, which provide fora for employers to provide input to programme design. In addition, there are many examples of industrial partners providing direct teaching input.

47. The **Constructionarium** is **an innovative for-credit course, allowing students to manage and build scaled down versions of real engineering projects** (such as the 'Gherkin' skyscraper) at a bespoke construction site provided and supported by the Construction Industry Training Board. Students are joined onsite by senior engineers from industry partners. The course aids the transition from theory to practice, converting students of engineering to student engineers. Since its inception, the project has been adopted by over 20 UK universities, owing to its unique project-based learning approach.

48. The College has extensive links with relevant companies to facilitate the completion of final year projects in collaboration with industry. For example, the new **Design Engineering** programme has links with over 150 companies which support a compulsory final year industrial placement. Visiting Professors drawn from industry also provide a valuable resource for ensuring that our programmes remain relevant to the needs of employers.

49. Imperial is committed to advancing the careers of women in STEM and has been recognised with an **Athena Swan Silver Award** at institutional level.[37] The **Althea-Imperial Programme** is a personal and professional development programme aimed at women and we celebrate the achievements of female staff and students , and raise awareness of support available for professional development and support, during our annual Women@Imperial week.

50. We must continue to challenge students and deliver a world-class educational experience that prepares them for a constantly changing world of work. Our **Excellence Fund for Learning and Teaching Innovation** has been a catalyst for generating innovative ideas for how we educate our students.[38]

Upgrading Infrastructure

51. Imperial is internationally renowned for high quality research into improving public and private sector infrastructure. This was recently recognised with a new **€15 million grant from the European Commission** to collaborate with the University of Cyprus to develop more efficient and resilient infrastructure in Cyprus. The **Railway and Transport Strategy Centre** is an applied research and consultancy division of researchers and consultants within the Department of Civil and Environmental Engineering. It specialises in mass transport in cities, international benchmarking and public transport operations, economics, management and engineering.

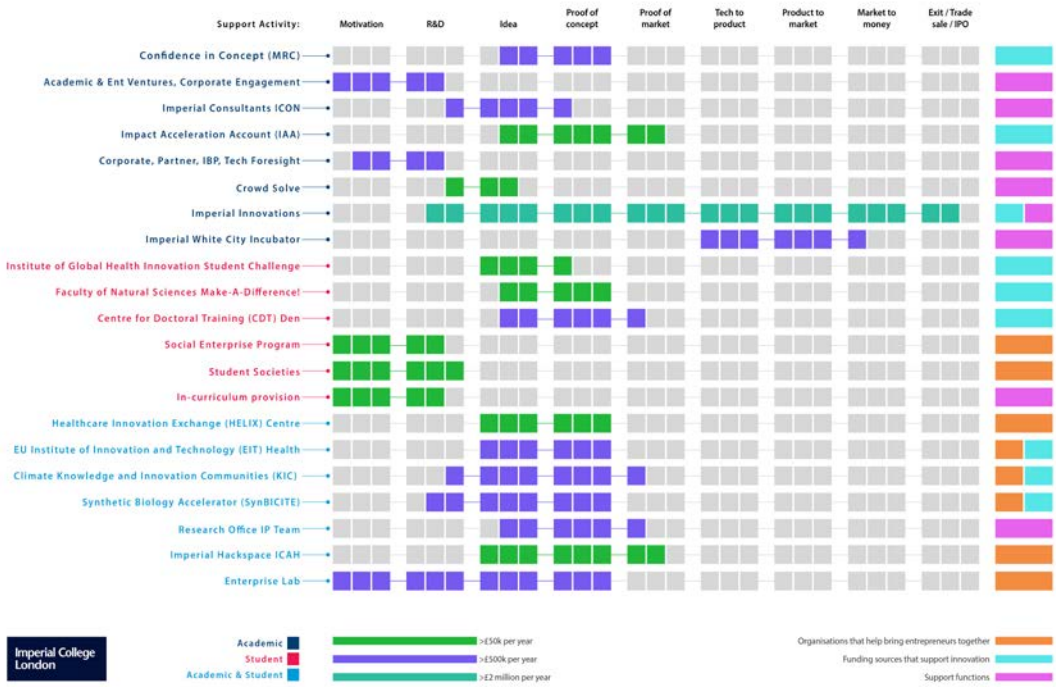
    - UKRI's new R&D capital spending roadmap should **focus support on developing research infrastructure within the UK's existing university estate**. UKRI will also **need sustainable funding for the on-going resource costs** associated with operating, maintaining and upgrading these world-class capital facilities.

[37] Athena Swan awards recognise commitment to advancing the careers of women in science, technology, engineering, maths and medicine (STEMM) employment in higher education and research
[38] See www.imperial.ac.uk/about/leadership-and-strategy/provost/vice-provost-education/the-excellence-fund-for-learning-and-teaching-innovation/

Supporting businesses to start and grow

52. As well as collaborating with established industry leaders Imperial has an established innovation ecosystem supporting start-ups from across our community at all stages of development (see Fig 2). For example facilities such as our **Advanced Hackspace** and **Enterprise Lab** provide access to cutting-edge prototyping technologies and workshops to help students, staff, alumni and commercial partners convert research ideas into breakthrough products and services. Successful prototypes then feed ideas and businesses into the **Incubator**, which offers flexible workspace and support for young businesses and spin-out companies.

Fig 2: Support activities at Imperial mapped across the entrepreneurial journey



53. The **Imperial Incubator is a hub for innovation and entrepreneurship**. In under a decade, 60 companies have grown within its walls, attracting £750 million ($1.2 billion) of investment. We are creating new spaces for start-ups, spin-out companies and entrepreneurs to work alongside Imperial at every stage of their development and growth. Our **Translation and Innovation Hub** at White City provides a home for businesses looking to turn cutting-edge research into new products and services. Professor Chris Toumazou, **founder of DNA Electronics** (which uses genomic analysis to develop fast, low-cost tools for patient diagnosis) is among the first wave of entrepreneurs to locate a spin-out company at the White City Campus.

54. These **spaces are often linked to specific research and development partnerships so collaboration with Imperial is embedded from the start**. Imperial is developing a shared lab incubator for micro-companies to rent-a-bench, alongside our existing White City Incubator. This would replicate models like QB3 in San Francisco, LabCentral in Cambridge Massachusetts and the Harvard LifeLab.

- We would like to encourage post docs to start companies in such a facility, progressing the ideas arising from their time in academic labs**. They would need a source of seed funding in order to do so**. In the US the Small Business Innovation Research programme is a common source of such funding and a similar scheme exists for start-ups in Munich.[39]

[39] See www.sbir.gov/about/about-sbir and www.muenchen.de/rathaus/wirtschaft_en/business-development/finance-funding.html

55. We look forward to sharing our experience creating an entrepreneurial culture with Professor Tim Dafforn's review. **The Imperial College Business School offers a range of programmes to help staff, students and industry develop entrepreneurial skills alongside technical ones.** For example a mini-MBA programme for science and medicine PhD graduates includes courses in business skills and commercial awareness; a unique MSc Innovation, Entrepreneurship & Management focuses on launching a new business, developing start-ups and consulting on innovation.

56. Businesses spanning more than 20 industries have sponsored employees to undertake an MBA with Imperial. Our **Executive Education programmes**, cover Innovation, Entrepreneurship and Marketing. The Business School also collaborates with the London Stock Exchange on the ELITE Programme focused on **maximising the growth of high potential SMEs**. The School also publishes thought leadership on issues facing SMEs and how public policy and private initiatives can support their growth.

57. We will contribute to the **Patient Capital Review** as the ISGP looks to universities for research that will drive innovation and considers how to better translate discovery into commercial enterprise. Patient capital for ideas that take longer to develop is a model that is particularly suitable for advanced technology businesses such as those emanating from university research.[40]

Encouraging trade and inward investment

58. Imperial is the **UK's most international university** and our **students, staff and international relationships** are vital to the quality and impact of our research and education.

59. We **attract new investments into the UK from global corporations and international partners across a range of sectors**, such as Petronas, AVIC, Nestle, Novo Nordisk, Johnson and Johnson, Huawei, NEC and Intel. We also help British businesses to reach further, our R&D collaborations with Rolls Royce are driving new opportunities in Singapore and around the world.

60. Most international students at Imperial return to their home countries after graduating, forging successful careers and maintaining connections with the UK, heightening our global influence. For example, **Chen Jining** completed a PhD in Civil Engineering at Imperial before serving as President of Tsinghua University and is now Environment Minister under President Xi Jinping. **Marc Garneau** completed a PhD in Electrical Engineering at Imperial before becoming the first Canadian in outer space and is now Transport Minister of Canada.

61. The ISGP notes the Government's commitment to building a truly global Britain and making the UK an attractive place to invest. Higher education is an incredibly valuable export sector that also attracts inward investment, beyond the billions in fees and expenditure that international students bring. **Imperial's Incubator** has attracted £1 billion of investment to UK spin-outs like Blocks – a multinational student and recent graduate-run firm behind the world's first modular smartwatch – and Cortexica, which is selling its image recognition technology, originally developed in Imperial labs, to some of the top US fashion houses.

62. We **support the GREAT campaign encouraging people to study in the UK**. In addition to the many economic and social benefits these students bring to the UK during their courses, our alumni are powerful ambassadors for British business and innovation. For example **Malav Sanghavi (India)** studied International Design Engineering at Imperial and the Royal College of Art and is staying in the UK with an Imperial-sponsored **graduate entrepreneur visa** to build a UK-Indian start-up selling innovative **low-cost baby incubators made of cardboard**, and **adjustable smart sockets for artificial limbs**.[41] Imperial graduate **Zehan Wang (China)** worked with his British coursemate Rob Bishop to found **Magic Pony**, a machine-learning visual processing tool. They sold the business to Twitter last year for $150 million and are helping to build Twitter's global AI research and development centre in London.[42]

[40] Written evidence submitted by Imperial, Commons Science and Technology Select Committee (October 2016)
[41] Malav employs people in R&D and manufacturing in both the UK and India – forging new trade connections – and was recently named in the Forbes 30 under 30 list as one of Europe's most exciting young entrepreneurs.

- The Government should **forge new global research networks** and co-fund more ambitious programmes to support collaboration with international partners like the US and China.

Delivering affordable energy and clean growth

63. Within Imperial, the **Grantham Institute** is committed to driving research in climate change and the environment, and translating it into real world impact. The Institute's researchers are developing both the fundamental scientific understanding of climate and environmental change, and the mitigation and adaptation responses to it. The research, policy and outreach work that the Institute carries out is based on, and backed up by, the world leading research by our academic staff. The **Energy Futures Lab** is a cross-discipline institute at Imperial that develops multidisciplinary, cross-faculty collaborations to tackle the broad range of energy challenges that the world faces.

64. The College's **Carbon Capture Pilot Plant** is a four-storey scaled-down chemical engineering plant providing a fully hands-on discovery experience for students and researchers alike. Built to the highest industrial standards, the plant is a core part of the training that the College provides to its chemical engineering students. The Carbon Capture Pilot Plant is also a vital resource in the fight against climate change, demonstrating best practice in capturing and storing harmful carbon dioxide before it can be released into the atmosphere. The College actively encourages leading industrial organisations to use this facility for research purposes.

Cultivating world-leading sectors

65. Research and development at the best universities underpins the creation and cultivation of new sectors. Universities are able to define new disciplines arising out of research and then educate cohorts of individuals in these new disciplines in way that responds to the needs of industry and academia. For example the discipline of **bioengineering (biomedical engineering)**, has been co-defined by research-intensive universities and industry and is continually evolving through those interactions.