IOP Institute of Physics
Scotland

Draft Energy Strategy and Just Transition Plan

Consultation response – May 2023

Introduction

The Institute of Physics (IOP) Scotland welcomes the opportunity to respond to the Scottish Government's Draft Energy Strategy and Just Transition Plan.

We are focusing our response on a few key areas – skills needs, diversity and inclusion, and the opportunities afforded by several key technologies with significant physics aspects – rather than commenting on detailed targets for the contributions to be made by specific technologies. But at the outset we want to set out why physics does and must continue to play a crucial role in providing energy and addressing climate change.

About us

The Institute of Physics is the learned society for physics and professional body for physicists across the UK and in Ireland. We seek to raise public awareness and understanding of physics, inspire people to develop their knowledge, understanding and enjoyment of physics and support the development of a diverse and inclusive physics community. Our mission as a charity is to ensure that physics delivers on its exceptional potential to benefit society.

Our flagship impact project for 2023, entitled "Physics Powering The Green Economy", will work to highlight how physics has enabled the green economy of today, set out how physics will enable the green economy of tomorrow, and build evidence to influence related national strategies and actions, and create impact.[1] We will happily share the outcomes of this project with the Scottish Government when these are published.

This project follows the IOP's podcast, which has had over 120,000 downloads, entitled *Looking Glass*:[2] Series 2 is devoted to "A Green Future" and series 3 is focused on "Climate Solutions". IOP Publishing (IOPP), a wholly owned subsidiary of the IOP and one of the world's leading publishers in physics and related disciplines, has several specific books and journals relating to energy and climate issues.[3] We also have special interest groups in both Energy and Environmental Physics.

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1 See www.iop.org/strategy/science-innovation/physics-powering-green-economy.

2 See www.iop.org/lookingglass.

3 IOP journals include *JPhys Energy*, *Progress in Energy*, *Nuclear Fusion*, *Environmental Research: Climate*, and *Environmental Research: Energy* (forthcoming). Related IOP science books include *Solving Climate Change: a guide for learners and leaders*, J Koomey and I Monroe (2022), and the

Why physics matters to the Energy Strategy

Physics and physicists must be at the heart of developing and delivering energy solutions. Energy itself is a core physics concept as well as a quantifiable property (or potential) affecting all matter with a mass. The laws of thermodynamics – partly codified by Lord Kelvin at the University of Glasgow – govern all processes converting from one type of energy to another in closed systems, which is what energy generation involves. From water wheels and hydro-electric dams to heat-powered engines such as steam, internal combustion and jets, potential or chemical energy from fuels have been converted into mechanical work and electricity, powering the industrial revolution and building the modern world, all the way to space travel.

Yet repeated combustion of fossil fuels has created a largely invisible toxic legacy which is disturbing the balance of planetary ecosystems.[4] It is incontrovertible that the Earth is warming, and that human activity – mostly burning hydrocarbons and releasing CO_2 – is the primary cause. Physicists were the first to observe, record, share, measure and explain this trend, since heat absorption within the atmosphere is also a basic, well-recognised physics concept.[5] Physicists have also helped to collect extensive data and predict global temperature rises under different scenarios. Even small overall rises would have drastic effects on the planet because of both accelerant effects and negative feedback loops (e.g. melting ice caps leading to sea level rises, greater heat retention within seas than ice shelves, increased coastal erosion, and potentially permanent effects on oceanography and currents).

We will still need power for all the things we need and want to do, and this is entirely possible, as the Earth's energy potential is abundant.[6] Obtaining what we need sustainably has become one of the most pressing social and economic challenges for the entire world. Physicists were the first to identify and quantify not only the opportunities to derive energy most efficiently and economically from fossil fuels, but also the environmental risks of doing so, and continue to do so.[7] Access to sufficient physics knowledge and skills, and technological innovation, will

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Renewable and Sustainable Power series. Several such publications are, or are moving towards, open access.

4 See, for example, Working Group I's contribution ("The Physical Science basis") at www.ipcc.ch/report/sixth-assessment-report-working-group-i/ to the sixth assessment cycle of the Intergovernmental Panel on Climate Change, at www.ipcc.ch/report/sixth-assessment-report-cycle/.

5 The atmosphere currently retains around 159W of heat more than the Earth emits into space for every m^2 of the Earth's surface. Without this, the Earth would be around 32°C cooler, and most of its surface would be uninhabitable. However, our civilisation (including urbanisation and agriculture) has developed around the climate balance in place during the past few centuries.

6 Fusion from the Sun releases 3.8 x 10^{23} kW every second. Despite being 93 million miles away, 1kW of this hits each square metre of the Earth (on a cloudless day, facing the Sun) every hour. This is equivalent to more than 8,500 times the amount of energy we currently use.

7 e.g. the GRACE (Gravity Recovery and Climate Experiment) and GRACE-FO (Follow-On) are two-satellite missions by NASA and DLR, the German Aerospace Centre. These missions have revealed vital information, such as: how much the deep oceans are warming and how the currents there are

therefore be essential to overcome the challenge of sustainable, affordable and secure energy generation.

The discovery of North Sea oil and gas fields in the 1970s transformed the UK and Scottish economies. Although production peaked in the late 1990s, the sector still contributes £8.8bn to Scottish GVA, and directly employs 57,000 people, with associated spin-off benefits from supporting industries. It also made North East Scotland a centrepiece of physics-based skills and productivity. Locating fields and determining their size, ease of extraction and likely productivity, involved substantial physics work and equipment. Oil exploration involved drilling down thousands of metres, using electromagnetic fields and waves, acoustic waves, neutron scattering, gamma-ray radiation, nuclear magnetic resonance (NMR), infrared spectroscopy, and pressure and temperature sensors within boreholes.[8] Similarly, this demand prompted significant improvements in instrumentation, modelling, and inversion techniques, allowing petroleum engineers to discover smaller petroleum reservoirs in more remote, complex, and difficult geological settings than ever before. Although we now know we will need to leave some of this potential untapped, it has created a skills and technology legacy to be proud of and which we will need to continue to reply upon. 16% of employment in Scotland is physics-based, higher than the 11% equivalent for the UK as a whole. Average salaries for physicists are also higher in Scotland (£47,000 compared with £42,000 in England), as is each role's economic productivity (£129,000 compared with £81,300 in England).[9] Scotland can ill-afford to lose this extent of talent, so the physics sector is more invested than most in ensuring a just transition from a fossil fuel-based to a renewable-based energy sector.

The approach of physicists to energy and climate change

> **"Following [Professor Kimberley] Nicholas, we summarize the current state of knowledge about the climate problem in a few phrases: It's warming. It's us. We're sure. It's bad. We can fix it (but we'd better hurry)."**[10]

There is a reasonable degree of consensus about the steps needed to solve the climate crisis.[11] Physics societies around the world recognise that physics has a central role in addressing the

changing; how major aquifers are drying out; how much moisture is in the soil and the total mass of ice (as opposed to area) that has been lost from the polar ice sheets. See https://gracefo.jpl.nasa.gov/.

8 See "Physics in Oil Exploration", B Clark & R Kleinberg, *Physics Today* 55 (4), pp 48–53 (2002)

9 See *The Contribution of Physics to the Scottish Economy*, IOP Scotland (2022) at https://www.iop.org/sites/default/files/2022-12/IOP-Contribution-of-Physics-to-the-Scottish-Economy-summary.pdf

10 *Solving Climate Change: A guide for learners and leaders*, J Koomey and I Monroe (2022). Citing, and adapting, *Under The Sky We Make*, K Nicholas (2021).

11 In Koomey and Monroe's book (see fn 10 above), for example, the authors assert that to stabilise the climate crisis, we must: end the use of fossil fuels, minimise non-fossil emissions, and create a climate-positive biosphere. Maintaining this position and building on it involves five technical actions (electrify

climate change issue and helping to build a green economy,[12] but also that this is a global challenge, requiring global agreement and action.[13]

Since every country on Earth and every community within them is invested in finding solutions which work, every country has committed to legally binding objectives via the Paris Agreement in 2015. This involves keeping global average temperature rises to below 2°C above pre-industrial levels, and seeking to hold them to 1.5°C, or as close as possible. As well as defined national emission contributions of greenhouse gases (GHGs), and requirements for long-term national strategies, there are provisions affecting finance, capacity-building and transparency. The Paris Agreement also recognises that technology must play a major role in addressing the climate crisis, both to reduce GHG emissions and to develop resilience and adaptation measures. The UK and Scotland are well-placed to lead on developing these technologies given our industrial heritage, capacity for innovation, and educated workforce.

Responses to consultation questions

Chapter 1 – Introduction and Vision

We are focusing our responses on questions which are most relevant for the physics-based approach set out in our introduction.

1. What are your views on the vision set out for 2030 and 2045? Are there any changes you think should be made?

We welcome the vision for "a flourishing, climate friendly energy system that delivers affordable, resilient and clean energy supplies for Scotland's households, communities and business." In particular, we welcome the ambition to quintuple renewable output between 2020 and 2045, but also the acknowledgement that significant efforts are required to decarbonise energy for heat, transport and industry, reform markets to ensure energy security and affordability, and to maximise the economic and social benefits from the transition to net zero.

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everything, decarbonise electricity, address non-fossil GHGs, maximise efficiency and optimisation, and remove carbon) and three structural ones (align incentives, mobilise money, and elevate truth). Commonly cited additional steps include reducing energy use where practicable, and recycling and re-using energy intensive materials.

12 See "A call to action: the role of physics in delivering the global green economy", signed by the International Union of Pure and Applied Physics, the IOP, and a dozen other national physical societies worldwide, at www.iop.org/strategy/physics-climate-change-sustainability/global-green-economy.

13 E.g. The European Physics Society's position on Climate Change, adopted before the 2015 UN Summit, when the UK was still an EU member, wrote "Europe cannot curb the increase in global CO2 emissions. Global action is required." (see https://cdn.ymaws.com/www.eps.org/resource/resmgr/policy/eps-pp-EuropeanEnergyPol2015.pdf).

We believe the Scottish Government should increase R&D funding for sustainable technologies, with a focus on developing an effective and economically viable low carbon electricity system, and work to encourage other funding providers to adopt similar ambitions. Together with carbon capture, use and storage, these are key to achieving a sustainable electricity future. As there is a rapidly growing world market for sustainable technologies, this will also create competitive advantages and a return on investment.

However, we think that the position statement on nuclear (i.e. "[w]e do not support the building of new nuclear power plants, which due to the high costs of nuclear, as well as taking decades to build, will do nothing to address the urgent imperative of driving down energy prices") does not draw a sufficient distinction between generation from nuclear fission and nuclear fusion. Para 3.2.4 of the Strategy presents a more balanced view, but it is also important to be clear within the vision.

The IOP supports better public understanding of the potential of fusion.[14] Existing nuclear fission technology involves splitting heavy atoms of substances like uranium, which are both radioactive and finite, like fossil fuels. Fusion, by contrast, involves joining together light atoms like deuterium and tertium, which are ions of hydrogen. These are distilled from water, creating a potentially limitless supply of fuel. No long-lived radioactive waste is produced and meltdown safety incidents (as at Fukushima, Japan in 2011) are not possible. The distinction has also been recognised in UK energy regulation, with fusion being regulated through the Environment Agency and Health & Safety Executive rather than the UK Atomic Energy Authority.

Fusion also releases four times the energy that fission does. If the Scottish Government's vision is to achieve "affordable, resilient and clean energy", fusion deserves serious consideration against that criteria. Unless and until solutions are found which can capture and store renewable-generated power on a sufficient scale, there will be a need for a reliable, non-carbon output to act as a baseload for demand when the wind doesn't blow and the sun doesn't shine.

This is particularly relevant since physicists at Lawrence Livermore National Laboratory in California announced a breakthrough in December 2022 by producing for the first time a nuclear fusion reaction that created more energy than was expended – a critical step in turning fusion generation theory into practice. A working reactor which generates enough energy to plug into the national grid requires further development, since fusion relies on extremes of pressure and heat to work. But the global fusion industry has moved from 83% of firms being confident that fusion will be on the grid in the 2030s or before to 93% in the space of one year,[15] based on both scientific advances and rapidly increasing investment following them.

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14 See, for example, *Nuclear fusion explained*, Professor Martin Freer, IOP Vice-President: www.iop.org/about/news/physics-explained/nuclear-fusion.

15 *The Global Fusion Industry in 2022*, Fusion Industry Association (2022). See https://202e0f23-02b6-4124-8ddc-80f6b1109b43.usrfiles.com/ugd/202e0f_4c69219a702646929d8d45ee358d9780.pdf.

The UK is participating in the Spherical Tokamak for Energy Production (STEP) programme, and the Fusion Forward consortium's site at Ardeer in North Ayrshire was one of the final five locations under consideration. North Ayrshire Council was part of the consortium, with the bid receiving support from diverse organisations such as Scottish Enterprise, Skills Development Scotland, the Scottish Council for Development and Industry, the Federation of Small Businesses and the Scottish Trades Union Congress. All of them saw the potential for regeneration and highly skilled, well-paid jobs in an area of socio-economic need. Collaboration was already planned to deliver the training and skills needs required to staff a reactor like this one in future, from apprenticeships to PhDs.

Fusion has been identified as an important element of achieving net zero in the Net Zero Review published by former UK Energy Minister, Chris Skidmore;[16] in the UK's 10 Point Plan for a Green Industrial Revolution;[17] and in the US Administration's top-five priorities for achieving net zero by 2050.[18] Leading industrial and research-based economies are embracing the potential of this technology, including the ITER project in France[19] and the KSTAR project in South Korea,[20] and we urge the Scottish Government not to leave Scotland behind.

We appreciate the concern about start-up costs, but since a working fusion reactor has not yet been built, all previous cost assessments associated with fission power plants are of limited value. The Scottish Government should at least analyse the demonstration projects for fusion now occurring elsewhere, and assess both the generation potential and life cycle costs of fusion projects in light of emerging evidence. Consideration of the applicability and potential role of fusion should be informed by analysis of evidence rather than ideology and a narrow understanding of the term 'nuclear' itself. The technology for fossil fuel extraction and field discovery improved massively to become more efficient and productive after the initial commitment to invest, and there is no reason to think a similar trend would not be seen here too.

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16 See www.gov.uk/government/publications/review-of-net-zero ("Government should ensure continued funding and support for new technologies such as advanced modular reactors (AMRs) and fusion that could play an important role in the future." (at p.99))

17 See www.gov.uk/government/publications/the-ten-point-plan-for-a-green-industrial-revolution at point 10 (p. 26): "We are doubling down on our ambition to be the first country in the world to commercialise fusion energy technology, enabling low carbon and continuous power generation"

18 See www.whitehouse.gov/briefing-room/statements-releases/2022/11/04/fact-sheet-biden-harris-administration-makes-historic-investment-in-americas-national-labs-announces-net-zero-game-changers-initiative/

19 See www.iter.org/org/ITERinFrance

20 See www.kfe.re.kr/menu.es?mid=a20202030100

Chapter 2 – Preparing for a Just Energy Transition

8. What further advice or support is required to help individuals of all ages and, in particular, individuals who are currently under-represented in the industry enter into or progress in green energy jobs?

Physics knowledge and skills generally will be significantly important in meeting skills needs. 70% of physics-based businesses have already said they have delayed or dispensed with plans to invest in innovation based on lack of available skills.[21] This situation would only intensify if publicly-driven demand for more green energy roles were competing with the existing physics sector, unless more is done to encourage and support others to develop physics-based knowledge and skills.

The IOP has responded to consultations in relation to the national discussion on education, the independent review of the skills delivery framework, and the independent review of qualifications and assessment.[22] These should inform the current programme of education reform, including the forthcoming Bill before the Scottish Parliament. We have also published *Subjects Matter*,[23] highlighting the need for more subject-specific professional learning for teachers, so that teachers themselves need to have excellent knowledge and understanding of their subject and how to teach it, which in turn gives students the best experience of subjects, encouraging them to excel while at school and to aspire to further success in the future.

We look forward to the publication of an updated Climate Emergency Skills Action Plan during 2023. The existing plan was one of the first policy documents in the UK explicitly to tie meeting skills needs for net zero with improving diversity and inclusion, and addressing under-representation in the sector.

The IOP has been committed to diversity and inclusion in physics for decades, especially by girls and young women. Recently we have seen more concrete evidence that persistent under-representation is also experienced by some ethnic minorities, some LGBT+ communities, people with disabilities, and those from poorer socio-economic backgrounds. Many of these groups show interest in science and physics in their primary schooling and early secondary, but are then dissuaded from pursuing it, often because of mistaken perceptions about what physics is and the type of people whom it suits or is for. This is a problem with broad implications because when young people are deterred from studying physics, they are missing out on the many benefits that studying physics brings. Crucially, they are also being denied the

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21 See *Paradigm Shift: unlocking the power of physics innovation for a new industrial era*, IOP (2021) at www.iop.org/strategy/productivity-programme/drivers-physics-innovation/paradigm-shift-uk and *Physics in Demand: The labour market for physics skills in the UK and Ireland*, IOP (2022) at www.iop.org/strategy/productivity-programme/workforce-skills-project.

22 Available at www.iop.org/policy/policy-statements-and-consultation-responses/education-and-skills.

23 See www.iop.org/about/publications/subjects-matter

opportunity to explore how their world works and contribute to shaping their future as informed citizens, and our society is deprived of their potential in these crucial fields.

To that end, we have established a **Limit Less campaign**[24] to support young people to change the world through physics. By changing perspectives of those whom younger people trust and listen to, and who help shape their opinions and decisions, we believe we can address this persistent issue of underrepresentation. We have produced careers resources to help inform teachers and careers advisers about the range of careers which physics opens doors to, and encourage them to pass this knowledge and inspiration on to pupils.

In schools, girls are persistently under-represented in physics. Of entrants on physics courses, 28% at National 5 level and 26% at Higher level are female. Physics is the fourth-most popular Higher subject for boys, but sixteenth-most popular for girls.[25] This imbalance persists and intensifies in further study and physics-related work – 25% of physics undergraduates are female, 22% of physics academic staff are, and only 12% of physics professors.[26] But the divergence is even more acute in non-academic physics careers. According to equality monitoring data on modern apprenticeships published by SDS, a mere 6% of modern apprentices in the engineering and energy sectors are female.[27] This has a greater impact than might first be assumed, since 53% of physics-based jobs do not require a degree, and a significant proportion of jobs we expect to be created in the renewables industry will be technical in nature but also be well-paid. Narrowing this extreme variance could have a notable impact on addressing the gender pay gap.

Unfortunately, subject choices are not broken down according to other equality characteristics, so we cannot tell the extent of disparities among other groups, despite such data being available in England. We hope the revised STEM Education and Training Strategy will commit to addressing this information deficit. We cannot prioritise or assess actions without knowing the scale of the issue or being able to see what effect specific interventions have. But evidence from elsewhere in the UK substantiates other forms of underrepresentation. This is especially important in Scotland because of the necessity of closing the poverty-related attainment gap – recently re-emphasised by the new First Minister, Humza Yousaf, in the statement of his Government's key priorities of equality, opportunity and community.

The Energy Strategy, Just Transition Plan and forthcoming revised Climate Emergency Skills Action Plan should follow through on this need and opportunity by identifying the specific

24 See www.iop.org/limit-less.

25 2022 Attainment Statistics, Scottish Qualifications Authority. See www.sqa.org.uk/sqa/105123.html

26 HESA data 2021/22: see www.hesa.ac.uk/data-and-analysis/

27 Skills Development Scotland modern apprenticeships monitoring data: 227 of 3,789 engineering and energy related MAs in training as at 30 December 2022. See https://www.skillsdevelopmentscotland.co.uk/media/49416/modern-apprenticeship-supplementary-tables-quarter-1-2022-23.xlsx

numbers of people who will be needed to fill the skills gaps presented by the Government's objectives and net zero targets, including increased numbers from currently under-represented groups. These numbers should then drive targets, commitments and actions by schools, training providers, colleges and universities.

This answer should also be considered as a response to question 44 (impact upon people in Scotland who share one or more protected characteristics under equality law, including disability, sex, gender reassignment, pregnancy and maternity, race, and sexual orientation).

Chapter 3 – Energy supply

Scaling up renewable energy

11. Should the Scottish Government set an ambition for marine energy and, if so, what would be an appropriate ambition? Please explain your views.

A specific ambition for marine energy would depend upon continued technological R&D, testing and refinements, but the potential is clear. Scotland is one of the top six locations worldwide for tidal energy research, and the 34 marine energy devices tested in and around Orkney over recent decades is more than any other location around the globe. This innovation has allowed considerable refinement and improvements to tidal technology, including the Orbital O2 and Mocean Blue X, and more than a dozen other projects described by the European Marine Energy Centre (EMEC).[28] The European Technology and Innovation Platform for Ocean Energy estimated that by taking the lead in the global ocean energy market, Europe would benefit from economic activity worth €140bn by 2050.[29]

There is also considerable potential for crossover benefits, as wave and tidal projects can generate green hydrogen for later use, especially off-grid uses such as transport. Any specific targets for sectors should take account of such forms of distributed benefits, and operate in such a way as to incentivise these opportunities.

13. Do you agree the Scottish Government should set an ambition for solar deployment in Scotland? If so, what form should the ambition take, and what level should it be set at? Please explain your views.

Development of solar deployment targets should take into account emerging evidence of increased capacity of solar cell technology. The Scottish Institute for Solar Energy Research (SISER) is working to create next generation converters to optimise the energy captured by solar cells.[30] This emphasises a wider point, that targets should not be fixed until 2045, but

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28 See www.emec.org.uk/marine-energy/wave-and-tidal-projects/.

29 See https://etipocean.us16.list-manage.com/track/click?u=ff0f81336e64a190eb1dc8fa7&id=e769a2fef3&e=59ab488846

30 See www.siser.ac.uk/research/next-generation.

repeatedly reviewed to take account of technology improvements which create more realistic capacity in different renewable sectors.

15. Our ambition for at least 5 GW of hydrogen production by 2030 and 25 GW by 2045 in Scotland demonstrates the potential for this market. Given the rapid evolution of this sector, what steps should be taken to maximise delivery of this ambition?

Hydrogen could play a significant role in meeting future energy needs, especially as a low-carbon energy source for vehicles. The anticipated market has been slower to emerge than expected because of higher than expected costs, technical difficulties and competition from rapidly improving battery technology for electric vehicles. However, hydrogen innovation is clearly worth pursuing as hydrogen is the most abundant element in the universe. Advanced science and engineering skills will be of crucial importance in developing and scaling up options, such as the potential of cryogenic liquid hydrogen and the opportunities afforded by developments in nanoscience for hydrogen storage and use.[31]

49. What are your views on the draft Just Transition outcomes for the Energy Strategy and Just Transition Plan?

The "Jobs, Skills and Economic Opportunities" section does not explicitly identify improving research capacity in sustainable energy as an outcome in itself or part of one. It is arguable that industry-based R&D could form part of "a continuously innovative and competitive energy sector", but it is likely that innovation will only continue and become more complex as technology develops and the renewable industry expands, as we saw in the oil and gas sectors. Having distinct research capacity to be able to drive and capitalise upon these opportunities could therefore be seen as an important benefit both in themselves and in the opportunities they create.

About this response

We are content for this response to be published. If you wish to follow up the issues raised in it, please contact:

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31 See *Next Steps for Hydrogen: Physics, technology and the future*, Institute of Physics (2016), available at www.iop.org/about/publications/next-steps-for-hydrogen.