ROBERT S DUTCH

A Christian perspective on the place of nuclear energy in achieving net zero and national security[1]

Abstract

We need energy. But what are potential solutions to achieving net zero? This paper presents a Christian perspective and overview of nuclear energy in the UK, and other countries, within the context of government policies to achieve net-zero emissions while ensuring national security. The growth of renewables is well-known but nuclear energy's positive contribution is often unrecognised in our energy mix for producing electricity. Nuclear provides clean, low-carbon baseload electricity and has its place alongside variable renewables in tackling climate change. Besides large reactors, small modular reactors (SMRs) are being considered within energy strategies. Beyond electricity generation, future nuclear plants offer cogeneration. Furthermore, nuclear plants do not create the air pollution associated with fossil-fuel emissions. This paper encourages people to become more informed about the place of nuclear energy by looking at an evidence-based approach and encourages discussion in an open, honest, and respectful way about its merits in protecting people and our planet.

Keywords: clean, low-carbon, net zero, pollution, reliable, renewables, security, SMRs, waste

Introduction

Climate change is here as the Intergovernmental Panel on Climate Change (IPCC) and the UK Met Office inform us. New UK record temperatures were set in 2021 and on 19 July 2022 the UK had its highest recorded temperature ever at 40°C.[2] The 2023 IPCC *AR6 Synthesis Report* summarises our current state

1 Additional information is available online at www.scienceandchristianbelief.org/ with details on: The UK's nuclear industry; Industrial Strategy and British Energy Security Strategy; Sizewell C Power Station and hydrogen production; Small modular reactors; Interconnectors and batteries; An international perspective post-Fukushima.

2 Met Office. What is climate change? www.metoffice.gov.uk/weather/climate-change/what-is-climate-change. See also: Met Office, Climate change in the UK, www.metoffice.gov.uk/weather/climate-change/climate-change-in-the-uk and Met Office, Key climate change indicators break records in 2021, www.metoffice.gov.uk/about-us/press-office/news/weather-and-climate/2022/key-

of knowledge, impacts, risks, mitigation, and adaptation. It states that impacts of a hotter, and changed world, on current and future generations depends on both current and near-term choices. Its press release summarises the considerable challenges in achieving climate justice: *Urgent climate action can secure a liveable future for all*.[3] The main cause is widely accepted to be the burning of fossil fuels, but how do nations make a just transition to a cleaner low-carbon world? Clean electricity supply systems are crucial in going green and have generated debate over the use of renewables versus nuclear electricity generation. This paper considers these power sources as complementary in dealing with the challenges of climate change and notes that flexible nuclear power has benefits that go beyond its traditional role of providing electricity. I endeavour to present an evidence-based examination of the place of nuclear energy in achieving net zero and national security that addresses those who wish to increase their understanding of nuclear energy. This paper references my book *Let There Be Light! Nuclear Energy: A Christian Case* which examines nuclear power's benefits, while chapters 5 and 6 address 'Concerns, Questions, Objections.' For example, chapter 6 covers safety, security, safeguards, accidents, and waste.[4]

Clarification on 'net zero'

The UK's Climate Change Act (2008) required legally binding reductions of emissions of carbon dioxide of 80% by 2050, compared with 1990 levels. It also appointed the Climate Change Committee (CCC) as an independent statutory body to advise the UK and devolved governments on emissions. The 80% figure was recommended to the Government by the CCC.[5] In 2019, the CCC recommended a new target of' net-zero greenhouse gases by 2050 based on the latest scientific evidence including the 2018 IPCC *Special Report on Global Warming of 1.5°C.* The Climate Change Act (2019) incorporated this more demanding target of 100% into law.

In May 2019, the CCC published *Net Zero – The UK's contribution to stopping global warming* in response to the governments of the UK, Wales, and Scotland request for a reassessment of the long-term emissions targets. It concluded: 'net-zero is necessary, feasible and cost-effective' and in reducing the

climate-change-indicators-break-records-in-2021.

3 IPCC. AR6 Synthesis Report: Climate Change 2023, www.ipcc.ch/report/ar6/syr/. Also IPCC. Urgent climate action can secure a liveable future for all, IPCC Press Release. www.ipcc.ch/report/ar6/syr/downloads/press/IPCC_AR6_SYR_PressRelease_en.pdf.

4 Dutch, R.S. *Let There Be Light! Nuclear Energy: A Christian Case*, Eugene, Oregon: Wipf & Stock (2017).

5 CCC. 'The UK's independent adviser on tackling climate change', www.theccc.org.uk It is also referred to as the Committee on Climate Change.

UK-produced emissions to zero, 'we also end our contribution to rising global temperatures.'[6]

Nevertheless, Dieter Helm regards this last statement as misleading because this net zero target 'is for territorial emissions *in the* UK'. It does not include imported carbon goods, or carbon consumption.[7] Helm sees the public misled, wasted years and failures. Mike Morecroft, president of the UK Christian charity The John Ray Initiative (JRI) and a Coordinating Lead Author for the IPCC notes that achieving net zero is not easy: it 'requires innovation, commitment and investment' plus it must support the poorest and vulnerable.[8]

Combatting climate change is not only about electricity production and related emissions but includes emissions from: agriculture; aviation; domestic and industrial heating; and transport.[9] Nevertheless, electricity is a major issue as we will use more of it to power electric vehicles, trains, domestic and industrial heating, and air conditioning. The UK's critical infrastructure, the National Grid, is being transformed through the incorporation of more renewables. However, wind and solar have drawbacks as the wind does not always blow and the sun does not always shine. Their intermittent nature means that other, more consistent, sources of electricity are required as well.[10]

It is important to address nuclear power because the public and Christian narratives often focus on the merits of renewables while neglecting nuclear's merits. Furthermore, silence, suspicion, or anti-nuclear arguments may hinder fruitful discussions and pro-nuclear supporters may self-silence for fear of adverse reactions. In my book I refer to the 'negative nuclear narrative' often used against the industry, while I advocate a more positive narrative, drawing upon my firsthand experience of being a scientist, engineer, tutor, and consultant in the UK's nuclear power industry. We need to talk, be truthful and transparent. Helm says we should tell the truth even if people do not like to hear about the UK's current energy system, intermittency, and exposure to global gas prices.[11]

6 CCC. Net Zero - The UK's contribution to stopping global warming, www.theccc.org.uk/publication/net-zero-the-uks-contribution-to-stopping-global-warming/.

7 Helm, D. *Net Zero: How We Stop Causing Climate Change*, London: William Collins (2020), pp. x-xii. On his book listen to the podcast Why Net Zero Doesn't Always Mean Net Zero, www.garp.org/podcast/not-net-zero-cr-210708.

8 Morecroft, M. JRI blog, What is Net Zero and why does it matter?, www.jri.org.uk/what-is-net-zero-and-why-does-it-matter/

9 See the report on public understanding: Institution of Mechanical Engineers, *Survey Results 2021*, February 2021. Public Perceptions: Greenhouse Gas Emissions, www.imeche.org/policy-and-press/reports/detail/public-perceptions-greenhouse-gas-emissions.

10 On myths, intermittency, and costs see: Helm, D. The first net zero energy crisis – someone has to pay 7 January 2022, www.dieterhelm.co.uk/energy-climate/energy/the-first-net-zero-energy-crisis-someone-has-to-pay-2/.

11 See his articles and videos at: Home - Dieter Helm, https://dieterhelm.co.uk/

Discussion is important in this contested area of energy, economy, environment, and ethics. When considering energy, national security is also crucial, as Russia's 2022 invasion of Ukraine demonstrates.

Talking about climate change

In 2020, Tearfund's Ruth Valerio asked: 'Why has the Christian faith not responded more wholesale and seriously to our climate crisis and caring for the natural world in general?' Her suggestions were barriers caused by: dualism, individualism, the new age, and the enlightenment. In May 2022, Emma Wyndham Chalmers (Tearfund – Australia) notes research indicated '35 per cent of senior church leaders say they rarely preach on environmental matters.' Why? Apparently, many saw politicisation of climate change as a key challenge. Yet many young Christian Australians are disappointed with the church's 'relative silence' and require more open talk.[12] Many years earlier, former Bishop of Birmingham Hugh Montefiore asked: 'Why aren't more church people interested in the environment?'[13]

Katharine Hayhoe, the Canadian evangelical Christian, and climate scientist advocates talking in a TED talk. Again, in her book *Saving Us: A Climate Scientist's Case for Hope and Healing in a Divided World* she reckons the most important action is talk.[14] Similarly, Emma Frances Bloomfield identifies communication strategies to engage US Christians in productive climate change conversations. After interviewing Christians from different denominations, she discovered their diverse views but encourages communication even with a controversial topic.[15] The Yale Climate Opinion Maps 2021 show that the estimated national average of US adults who 'think global warming is happening' is 72 per cent but the national average for those who talk about it 'at least occasionally' is just 35 per cent.[16]

12 Chalmers, E.W. The end of the climate wars is only the beginning: How Christians can improve the public conversation over climate change - ABC Religion & Ethics 30 May 2022, www.abc.net.au/religion/end-of-the-climate-wars-is-only-the-beginning/13905894.

13 Montefiore, H. *Why aren't more church people interested in the environment?* In: A Christian Approach to the Environment, Carling, R.C.J. and Carling, M.A. (Eds.) pp. 5-18. The John Ray Initiative (2005).

14 Hayhoe, K. The most important thing you can do to fight climate change: talk about it - TED Talk (November 2018), www.ted.com/talks/katharine_hayhoe_the_most_important_thing_you_can_do_to_fight_climate_change_talk_about_it. Also: Hayhoe, K. *Saving Us: A Climate Scientist's Case for Hope and Healing in a Divided World,* New York: One Signal Publishers (2021).

15 Bloomfield, E.F. Understanding Christians' climate views can lead to better conversations about the environment The Conversation 5 August 2019. www.theconversation.com/understanding-christians-climate-views-can-lead-to-better-conversations-about-the-environment-115693 .

16 Marlon, J., Neyens, L., Jefferson, M., Howe, P., Mildenberger, M., & Leiserowitz, A. Yale Climate Opinion Maps 2021 - Yale Program on Climate Change Communication. www.climatecom-

Talking about nuclear energy

In the UK, many people, including environmentalists and Christians, portray themselves as pro-renewables but are less inclined to self-identify as pro-nuclear. However, I consider that nuclear energy offers an important contribution to solving our climate crisis and energy security. Traditionally, most Greens have opposed nuclear energy e.g. Greenpeace's '6 reasons why nuclear energy is not the way ….' asserts it 'is often hailed as a magic bullet solution'. [17] But I am not claiming this, rather I am convinced it has an ongoing valuable place.

A public communications approach is advocated by the UK's Nuclear Industry Council (NIC) on effective engagement, since public support for nuclear 'is fragile and cannot be taken for granted,' rather, the industry must improve. It shared four principles, noting in Principle 2 Best practice, that public engagement will be characterized by: dialogue, trust, clarity, and consultation.[18] The UK's National Nuclear Laboratory (NNL) played a key role in developing the *Concordat* as did public dialogue participants.[19]

Talking about climate solutions should be done with respect and in love. For example, US climate scientist Michael M. Mann – who I once heard speak at Bristol University – explained how he was badly treated by powerful politicians. Now Mann supports use of *existing* nuclear plants until their retirement but does not support new nuclear. Nevertheless, he offers a paradigm with: 'There is a good-faith argument to be made, for example, that nuclear energy should be part of the solution, and I have colleagues whom I deeply respect who are bullish on the role it might play …,'[20] Billy Gates' *How to Avoid a Climate Disaster* presents a detailed discussion for supporting new nuclear build. Of course, climate change is not solely about technology, and government policies, but families, friends, foes, future generations, health, biodiversity, and our

munication.yale.edu/visualizations-data/ycom-us/. For further research see: Alper, B.A. How Religion Intersects With Americans' Views on the Environment Pew Research Center 17 November 2022. https://www.pewresearch.org/religion/2022/11/17/how-religion-intersects-with-americans-views-on-the-environment/.

17 Leman, M. 6 reasons why nuclear energy is not the way to a green and peaceful world. Greenpeace 18 March 2022. www.greenpeace.org/international/story/52758/reasons-why-nuclear-energy-not-way-green-and-peaceful-world/

18 NIC. *Nuclear Energy and Society: A Concordat for Public Engagement.* December 2015, pp. iii, 2. https://tinyurl.com/bdh29425

19 NNL. Public Dialogue Study On Nuclear Sector Communications. www.nnl.co.uk/innovation-science-and-technology/showreel/public-engagement/public-dialogue-study-on-nuclear-sector-communications/. See the link to the 2016 PowerPoint: *Findings of a public dialogue on how the nuclear industry engages and communicates with society on nuclear energy issues*. www.nnl.co.uk/wp-content/uploads/2019/12/IP20038.590061003-Nuclear-Energy-Society-Summary-Visual-Report.pdf.

20 Mann, M.M. *The New Climate War: the fight to take back our planet*, London: Scribe Publications (2021), pp. 169-171.

shared planet. Communicating climate change and investigating all solutions is essential.

There are pro-nuclear voices from people not claiming to be Christians (as far as I know). Respected veteran British environmentalist James Lovelock was a long-standing pro-nuclear proponent as he demonstrates in *The Revenge of Gaia* (2006). Under 'The Right Mix of Energy Sources' he makes a strong case for nuclear while recognising it is not a panacea but essential in an energy portfolio.[21] Further, American author Gwyneth Cravens, began a mission to investigate, and understand, nuclear energy as a sceptic but changed her views as documented in her informative book: *Power to Save the World: The Truth About Nuclear Energy* (2007). Mark Lynas, the environmental writer, and activist, who wrote *Six Degrees: Our Future on a Hotter Planet* (2007) also authored *Nuclear 2.0: Why a Green Future Needs Nuclear Power* (2013).

Scientist and former investment banker, Mathew Hampshire-Waugh's *Climate Change and the Road to Net-Zero* provides evidence-based discussions on energy sources and solutions. Chapter 7 'Sustainable Energy' is particularly relevant. He sees nuclear energy, even with four major accidents, as 'statistically the safest energy source with no dangerous atmospheric emissions.' Much of his evidence-based material is available online.[22] Michael Shellenberger's *Apocalypse Never* also provides extensive evidence on nuclear's merits.[23]

In June 2021, the University of Manchester's Dalton Nuclear Institute published its detailed report: *Nuclear energy for net zero: a strategy for action*. Here Francis Livens stated that reaching net zero by the 2050 target 'is extremely ambitious' and we should not underestimate the effort. Moreover, he said that the development of new reactor technology is needed now. It 'must be developed, demonstrated, licensed and built by the 2040s.'[24] Eight recommendations support the nuclear section to achieve its potential. Moreover, recommendation six says that the Climate Change Committee's 'net zero path' should examine an enlarged role for nuclear.

Further, in June 2022 a significant in-depth report *Beautiful Nuclear: Driving*

21 Lovelock, J. *The Revenge of Gaia: Why the Earth is Fighting Back – and How We Can Still Save Humanity*, London: Allen Lane (2006), pp. 87-105.

22 Hampshire-Waugh, M. *Climate Change and the Road to Net-Zero*, London: Crowstone Publishing (2021), p. 196. The accidents were: SL1 explosion in Idaho (US, 1961); Three Mile Island (US, 1979); Chernobyl (Russia, 1986); and Fukushima (Japan, 2011). His website is NET-ZERO, www.net-zero.blog/.

23 Shellenberger, M. *Apocalypse Never: Why Environmental Alarmism Hurts Us All*, New York: HarperCollins (2020).

24 Bodel, W., Butler, G., & Matthews, J. Nuclear energy for net zero - Dalton Nuclear Institute - The University of Manchester June 2021, foreword. www.dalton.manchester.ac.uk/nuclear-energy-for-net-zero/

Deep Decarbonisation began by quoting committed environmentalists George Monbiot, Mark Lynas, and Chris Goodall: 'our conversion to the cause of nuclear power was painful and disorienting. All of us carried a cost in changing our position, antagonising friends and alienating colleagues. But we believe that shutting down — or failing to replace — our primary source of low carbon energy during a climate emergency is a refined form of madness.' It shows how nuclear contributes to the UN's Sustainable Development Goals (SDGs).[25]

What then about the positions of green groups? Bishop Montefiore was an environmentalist who became pro-nuclear but had to leave his position in Friends of the Earth for his clear stance. Greenpeace maintains its opposition to nuclear. Former Extinction Rebellion spokesperson Zion Lights left the movement after becoming dissatisfied that it did not offer solutions. She became a pro-nuclear advocate and stated that instead of the green movement's anti-nuclear position she considered 'any rational, evidence-based approach shows that a strategy including nuclear energy is the only realistic solution to driving down emissions at the scale and speed required.'[26] She founded the website 'Emergency Reactor.'

The website 'Greens for nuclear energy' notes that members increasingly support nuclear; it aims to influence the green movement to change its oppositional stance. Its Home page respectfully urges 'fellow Green Party members to approach the nuclear power debate with an open mind and not fall victim to the "easy way out" of dogmatic, hard-wired anti-nuclear ideology.' This is amplified in its film 'Critical.'[27] A January 2022 poll, conducted in the UK by Ipsos on behalf of 'Greens for Nuclear Energy,' revealed the broad support of nuclear by most people 'involved in environmental campaigning organisations.' A November 2022 poll, confirmed 'people involved in environmental campaign organisations … are more likely to support than to oppose the use of nuclear energy for electricity production in the UK.'[28]

25 Gogan, K., Ingersoll, E., Partanen, R., Tiemann A., & Vysatovaet, R. *Beautiful Nuclear: Driving Deep Decarbonisation*, LucidCatalyst 2020. www.lucidcatalyst.com/_files/ugd/2fed7a_a69448de67fa47918bca4efa749d67db.pdf.

26 BBC. Extinction Rebellion: Nuclear power 'only option' says former spokeswoman. 10 September 2020. https://www.bbc.co.uk/news/uk-54103163. Also see: Lights, Z. 'Why I rebelled against Extinction Rebellion... and went nuclear: In an astonishing and brave volte-face, the eco-group's ex-spokesperson ZION LIGHTS reveals why she has changed tack over the future of energy', *MailOnline* 10 September 2020, www.dailymail.co.uk/debate/article-8716403/XRs-ex-spokesperson-ZION-LIGHTS-reveals-changed-tack-future-energy.html.

27 Greens for Nuclear Energy. 'No compromise to combat climate change: A Green Party Nuclear Energy Policy fit for the 21st Century', 2020. www.greensfornuclear.energy/.

28 Greens for Nuclear Energy. Green sympathisers support nuclear energy, across a range of questions. February 2022, www.greensfornuclear.energy/green-sympathisers-support-nuclear-energy/. Also see: Green sympathisers STILL support nuclear energy, across a range of questions. November 2022. www.greensfornuclear.energy/green-sympathisers-still-support-nuclear-energy-across-a-range-of-questions/

Lynas recently published an article about Finland's Green Party and its change to endorse a pro-nuclear stance in its national meeting and manifesto. The Vice chair and Leader of the Green parliamentary group, Atte Harjanne, states regarding the challenge: 'we need all sustainable tools: wind, solar and nuclear.'[29] Finland's Green Party is the first in the world to make this historic change. I hope that other green parties will follow their example.

Over decades, anti-nuclear groups have publicly voiced their opposition. I am aware of this from employment, from 1970, at nuclear plants as a young scientist involved in radiation protection and environmental monitoring. But what are public perceptions? I offer two examples. Nuclear's roles are frequently underappreciated as the UK's Department of Business, Energy and Industrial Strategy (BEIS) demonstrates in its *Public Attitudes Tracker Spring 2022*. For example, in Winter 2021 people were asked: 'From what you know, or have heard about using nuclear energy for generating electricity in the UK, do you support or oppose its use?' The percentage total support was 37% (with 13% strongly supported), while the total opposed was just 14% (with 6% strongly opposed). However, 49% did not have an opinion (28% neither supported or opposed while 21% did not know). On small modular reactors (SMRs) 54% of people had never heard of them and another 39% 'know a little or hardly anything.'[30]

In 2022, YouGov conducted, a public survey on nuclear energy for the Radiant Energy Group – published in the *State of Nuclear Energy Support in the UK and its Driving Forces*.[31] This survey is part of the Nuclear Confidence Project which aims to educate the nuclear industry by tracking public perceptions on clean energy sources and drivers on attitudes. The summary report recognises that nuclear 'has record public support'. However, the industry needs to communicate better with the public, understanding what motivates them to act – hopes and ambitions – not just fears.

Christian contributions

So where do Christians and churches stand in this important dialogue on climate change solutions and energy security?[32] I address this topic in my book's

29 Lynas, M. Finland's Green Party endorses nuclear power - Alliance for Science, 23 May 2022, www.allianceforscience.org/blog/2022/05/finland-green-party-nuclear/

30 BEIS. *Public Attitudes Tracker: Energy Infrastructure and Energy Sources, Spring 2022, UK*, pp. 21-23, 16 June 2022. www.gov.uk/government/statistics/beis-public-attitudes-tracker-spring-2022.

31 The summary, with a link to the full report, is: Radiant Energy Group. 'State of Nuclear Energy Support in the UK and its Driving Forces', August 2022, https://www.radiantenergygroup.com/reports/state-of-nuclear-energy-support-in-the-uk-and-its-driving-forces?mc_cid=f6f13be1aa&mc_eid=753f1a3943.

32 For further discussion see Dutch, *ibid*. chapter 4 'Energy Policies and Positions' with a section

chapter 4 'Energy Policy and Positions,' but it is worth revisiting. And I should say that in the nuclear industry where I worked as a Christian there were other Christians, and those of other faiths, or none. This remains the case today.

There is a spectrum of views. In 2006, Christian Ecology Link (CEL, now Green Christian) published *FAITH AND POWER: The Case for a Low Consumption, Non-Nuclear Energy Strategy*. This paper gives useful principles and received support from church leaders but its anti-nuclear stance is clear. In contrast, Christian author Ian Hore-Lacy, while working for the World Nuclear Association, had published in *Science and Christian Belief* 'Nuclear Power and Energy Sustainability' (2011), contending: 'Christian stewardship of God's creation in applying its bounty to human needs appropriately involves utilising nuclear power more widely'.[33] He observes its section 'Christian Principles to underpin Energy Strategy' is 'unexceptional', but in 'Assessing the Nuclear Option' he saw, from his first-hand experience, 'many errors and misrepresentations.'[34] He provides informed arguments for evaluating nuclear energy as God's provision in creation. Baptist minister John Weaver, in *Christianity & Science*, helpfully addresses the nuclear energy option. Moreover, he points out that renewables are not 'entirely problem free.'[35]

In *The Cambridge Companion to Christian Ethics* (2012), Michael S. Northcott addressed 'Ecology and Christian Ethics,' but only has a passing note on nuclear.[36] Sadly, Martin J. Hodson & Margot R. Hodson's *A Christian Guide to Environmental Issues* (2021) in chapter 6 'Energy,' too quickly dismiss nuclear noting people's concern over safety and waste. With both fossil fuels and nuclear dismissed they focus on renewables. This does not do justice to the topic when in a climate crisis we must examine all possible solutions.

My book's pro-nuclear contribution, is endorsed by both Anglican and Baptist Christians with a foreword from Kenneth Stewart (former Director of Pastoral and Mission Studies at Bristol Baptist College). See the review by John Weaver.[37]

It is essential for Christians to be scientifically informed as a recent US article notes 'Nuclear fusion discovery promises clean energy: Why Christians

'Churches and Christians'.

33 Hore-Lacy, I. 'Nuclear Power and Energy Sustainability', Science & Christian Belief (2011) 23(2), p. 159-176.

34 *ibid*., p. 175.

35 Weaver, J. *Christianity & Science*, London: SCM Press, 2010, pp. 189-190.

36 Gill, R. (ed.) *The Cambridge Companion to Christian Ethics*, 2nd edition, Cambridge: Cambridge University Press, 2012. Chapter 16.

37 Weaver, J. 'Is there a Christian case for Nuclear Energy?' JRI Blog 9 August 2017. www.jri.org.uk/is-there-a-christian-case-for-nuclear-energy-by-rev-dr-john-weaver/.

should be scientifically savvy'.[38] Thankfully, the Anglican Community Science Commission (ACSC, formally launched 2022) assists the whole communion and faith leaders to embrace science and become confident to speak into the debate. According to Andrew Briggs, ACSC aims to equip Church bishops for 'leadership in issues involving science,' seeing science as God-given.[39] In its inaugural meeting video Archbishop Justin Welby spoke of the benefits of science. However, he remarks that the Church's reaction to science until today, has been very cautious. Or, he says 'there is fear …. We talk about all kinds of things that lead to people being frightened.'[40] My hope is that the ACSC will sensitively evaluate nuclear's merits.

This paper focuses on facts and evidence because ignorance of basic facts is widespread. I recognise that science alone may not change people's minds – fears, perceptions, ideology, politics, and worldviews are influencing factors. Further discussion occurs in Katharine Hayhoe's *Saving Us*, chapters 4-6 'The Facts Are the Facts,' 'The Problem with Facts,' and 'The Fear Factor'. I recognise that nuclear power and radiation may produce fear even though radioactivity is naturally occurring, as I have explained in my briefing paper.[41] Another reason I focus on facts is because of the prevalence of disinformation, explained by James J. McCarthy in 'Climate science and its distortion and denial by the misinformation industry'.[42]

Also, the prominent Christian atmospheric scientist, Sir John Houghton, while raising suitable questions on energy security with gas and nuclear, addressed nuclear's benefits.[43] Houghton, in his extensive work through the IPCC, briefing papers, conference speeches, books etc., has deeply influenced many, including this author. His autobiography *In the Eye of the Storm* admirably dem-

38 Legg, M. 'Nuclear fusion discovery promises clean energy: Why Christians should be scientifically savvy', 12 January 2023. www.denisonforum.org/current-events/science-technology/nuclear-fusion-discovery-promises-clean-energy-why-christians-should-be-scientifically-savvy/.

39 Anglican Community News Service. 'Anglican Communion Science Commission meets for the first time', 8 December 2021, www.anglicannews.org/news/2021/12/anglican-communion-science-commission-meets-for-the-first-time.aspx. Also see: Ashworth, P. 'Lambeth 2022: New Science Commission launched', *Church Times* 6 August 2022. www.churchtimes.co.uk/articles/2022/12-august/news/world/lambeth-2022-new-science-commission-launched.

40 ACNS – Anglican News Service. 'Scientists and theologians join forces for new Anglican Communion Science Commission', 21 May 2022, www.anglicannews.org/news/2021/05/scientists-and-theologians-join-forces-for-new-anglican-communion-science-commission.aspx.

41 See Dutch, R.S. *Natural Radioactivity, Radiation Exposure and Our Environment*, JRI Briefing Paper No. 37 July 2018, www.jri.org.uk/wp-content/uploads/2018/08/BP37_Natural_Radioactivity_Dutch.pdf.

42 McCarthy, J.J. 'Climate science and its distortion and denial by the misinformation industry', in White, R.S. (ed.) *Creation in Crisis: Christian Perspectives on Sustainability*, London: SPCK (2009), pp. 34-52.

43 Houghton, J. *Global Warming*: *The Complete Briefing*, 5th edition, Cambridge: Cambridge University Press (2015), p. 301.

onstrates communicating climate science.[44]

In September 2019, the prominent Christian climate scientist Katharine Hayhoe was named by the United Nations Environment Programme as a Champion of the Earth.[45] Further, on 1st June 2021 she began her role as the Chief Scientist for The Nature Conservancy (TNC).[46] She takes a less positive view of nuclear energy. In *Saving Us* she comments on reactors in the US and UK, concluding that despite their enthusiasts they are not 'the all-encompassing antidote.'[47] And I agree but nuclear merits a place with renewables. Further, she states the US has not constructed new nuclear plants in thirty years – citing the failed attempt in South Carolina. But she has overlooked the construction of two AP1000 reactors in Georgia: Plant Vogtle units 3 and 4 – scheduled to produce power in 2023 and 2023/24 respectively and generate enough electricity for 500,000 homes and businesses. Plant Vogtle is part of achieving net zero by 2050 by preventing around 10 million tons of carbon dioxide emissions annually.[48] These reactors will operate for 60 to 80 years.

As mentioned, Hayhoe is the Chief Scientist for the NC which published its helpful 2022 report *The Science of Sustainability.* This investigates 'Two Paths to 2050' using the 17 measures of the UN's SDGs: a vision of 'a world where all people are fed, healthy, employed, educated, empowered and thriving, but not at the expense of other life on Earth.'[49] The report examines climate, energy, and air pollution under two scenarios: 'Business-as-usual' and 'Sustainable Path'. The Business-as-usual energy portfolio has: fossil fuels (76%), renewable energy (16.2%) and nuclear energy (7.8%). The Sustainable Path scenario has the following worldwide values by 2050: fossil fuels (13%), renewable energy (54%) and nuclear energy (33%). This mitigation from fossil fuels to renewables and nuclear energy has two advantages: 'First, it lowers the rate

44 Houghton, J., with Tavner, G. *In the Eye of the Storm: The Autobiography of John Houghton*, Oxford: Lion Books (2013).

45 AGU. 'Katharine Hayhoe Named United Nations' Champion of the Earth', Eos 100 (2019), doi.org/10.1029/2019EO133755.

46 TNC. 'Katharine Hayhoe', https://www.nature.org/en-us/about-us/who-we-are/our-people/katharine-hayhoe/ See her biography at BIO – Katharine Hayhoe; http://katharinehayhoe.com/biography/. Also Katharine Hayhoe - Every Reason to Care, Biologos 2021, https://biologos.org/podcast-episodes/katharine-hayhoe-every-reason-to-care.

47 *op.cit*., Hayhoe, pp. 170-171.

48 *op.cit*., Hayhoe, p. 169 footnote. See Bechtel. 'Building the future of carbon-free nuclear energy: Plant Vogtle Units 3 and 4', 2022, www.bechtel.com/projects/plant-vogtle-unit-3-4/. Also see: Georgia Power. 'Vogtle Unit 3 reaches 100 percent energy output for the first time', 29 May 2023. www.georgiapower.com/company/news-center/2023-articles/vogtle-unit-3-reaches-100-percent-energy-output.html.

49 TNC. The Science of Sustainability: Exploring a Unified Path for Development and Conservation, 13 October 2018. www.nature.org/content/dam/tnc/nature/en/documents/TNC_TheScienceOfSustainability_04.pdf.

at which greenhouse gases are flowing into the air, taking carbon projections down … compared to business-as-usual estimates …. Second, it would create a marked decline in air pollution and the amount of people subject to unhealthy air.'[50] TNC models show a reduction where half the world's population are exposed to poor quality air to just 7% of the world's inhabitants exposed in the Sustainable Path.

In 2023, Peter Bussey contributed in his Christians in Science blog: 'Nuclear power does not exclude or sideline wind generators and solar panels, but these have their own drawbacks and limitations. It is our human and Christian obligation to support all efforts that can provide energy that we need, but also preserve our planet for present and future generations!'[51] This beautifully summarises our situation. I consider that ignorance of basic facts, plus inexact presentations, and disinformation need challenging and church leaders need to be reliably informed to guide the flock in their charge, not out of fear but in love.

The International Energy Agency (IEA)

In 2014 and 2015, the IEA identified the important contribution of nuclear energy in preventing climate change stating using nuclear: 'has avoided the release of 56 Gt of CO_2 since 1971, equivalent to almost two years of global emissions at current rates.'[52] This demonstrates the misrepresentation from those who argue that nuclear is too late to mitigate climate change. Then in May 2019, the IEA published *Nuclear Power in a Clean Energy System*. Its first report on nuclear power in nearly two decades returned nuclear to the important worldwide energy debate. It recognises the significant role of nuclear power and hydropower as together globally they deliver three-quarters of low-carbon generation. Among its key findings is: 'Nuclear power is the second-largest source of low-carbon electricity today, with 452 operating reactors providing 2700 TWh [terawatt hours] of electricity in 2018, or 10% of global electricity supply.' The IEA recognises: 'Alongside renewables, energy efficiency and other innovative technologies, nuclear can make a significant contribution' to sustainable energy goals and energy security.[53] It states we cannot ignore nuclear.

50 *ibid*., p. 10.

51 Bussey, P. 'Nuclear power – fusion and fission', Christians in Science blog 3 January 2023. www.cis.org.uk/blog-3rd-jan-2023-nuclear-power-fusion-and-fission/

52 IEA. *Energy and Climate Change: World Energy Outlook Special Report*, OECD/IEA, 2015, p. 73, https://iea.blob.core.windows.net/assets/8d783513-fd22-463a-b57d-a0d8d608d86f/WEO2015SpecialReportonEnergyandClimateChange.pdf. This references a 2014 IEA report: *The Power of Transformation: Wind, Sun and the Economics of Flexible Power Systems*.

53 IEA. *Nuclear Power in a Clean Energy System*, Fuel report May 2019 pp. 3-4. https://iea.blob.core.windows.net/assets/ad5a93ce-3a7f-461d-a441-8a05b7601887/Nuclear_Power_in_a_Clean_Energy_System.pdf.. For the shorter report see Nuclear Power in a Clean Energy System – Analysis

Further, in 2021 the IEA issued *Net Zero by 2050: A Roadmap for the Global Energy Sector*.

In March 2022, following Russia's invasion of Ukraine, the IEA published *A 10-Point Plan to Reduce the European Union's Reliance on Russian Natural Gas*. Action 5 stated: 'Maximise generation from existing dispatchable low-emissions sources: bioenergy and nuclear.' Then, in June 2022, it published *Nuclear Power and Secure Energy Transitions: From Today's Challenges to Tomorrow's Clean Energy Systems*.[54] Its executive summary states nuclear: **'**can help make the energy sector's journey away from unabated fossil fuels faster and more secure' and 'Extending nuclear plants' lifetimes is an indispensable part of a cost-effective path to net zero by 2050.' Its *World Energy Outlook 2022* Flagship report recognises that Russia's invasion has caused 'a global energy crisis.' Moreover, in some countries nuclear is coming back into favour and there are lifetime extensions for current reactors, and announcements of new construction. The world's largest new build of nuclear is in China. The report indicates concern over the rising demand for critical materials used in clean energy technologies notably silver, silicon, and rare earth elements for wind turbines plus lithium for batteries. These materials are 'highly concentrated geographically.'[55]

In its informative *Electricity Market Report 2023*, the IEA recognised the joint role of renewables and reactors under the title 'Low emissions sources are set to cover almost all the growth in global electricity demand by 2025' commenting that over the next three years renewables and nuclear together: 'will dominate the growth of global electricity supply … meeting on average more than 90% of the additional demand.'[56]

The UK's nuclear industry

The remaining sections provide evidence from the UK, and worldwide, on the continued use of nuclear energy based on its merits at providing clean low-carbon energy and energy security**.** We need an electricity supply system that meets rising demands while functioning in extreme conditions.

- IEA Quote from Executive Director Fatih Birol, www.iea.org/reports/nuclear-power-in-a-clean-energy-system.

54 IEA. *Nuclear Power and Secure Energy Transitions: From Today's Challenges to Tomorrow's Clean Energy Systems*, June 2022, www.iea.org/reports/nuclear-power-and-secure-energy-transitions. Executive summary – A New Dawn for Nuclear Energy, June 2022, https://www.iea.org/reports/nuclear-power-and-secure-energy-transitions/executive-summary.

55 IEA. *World Energy Outlook 2022*, October 2022, pp. 47-48. https:/iea.blob.core.windows.net/assets/830fe099-5530-48f2-a7c1-11f35d510983/WorldEnergyOutlook2022.pdf

56 IEA. *Electricity Market Report 2023*, February 2023, p. 6. https://iea.blob.core.windows.net/assets/255e9cba-da84-4681-8c1f-458ca1a3d9ca/ElectricityMarketReport2023.pdf.

The UK has operated large nuclear power plants for many decades using Magnox reactors (now being decommissioned), Advanced Gas-cooled reactors (AGRs) and one Pressurised Water Reactor (PWR) at Sizewell B (East Suffolk). At its peak (around 1995) 25% of the nation's electricity was generated by firm and clean low-carbon nuclear energy in the days before renewables' rapid growth. Indeed, from 1983-1998 of the low carbon electricity supplied to the grid over 90% came from nuclear power.[57] This historic data shows the major contribution by nuclear power. If these plants had not operated the nation would have had more fossil-fired generation emitting more greenhouse gases and air pollution.

The AGRs are approaching, or have reached, the ends of their operating lives. Three plants are shutdown (with 6 reactors). The closure dates for the remaining AGRs were: Hartlepool and Heysham 1 (2024), Heysham 2 (2028), and Torness (2028). However, in March 2023, EDF announced it had a revised target date for Hartlepool and Heysham 1 of 2026. Nevertheless, this is subject to assessment by the independent Office for Nuclear Regulation (ONR).[58] But by 2028 all AGRs will be shutdown leaving only Sizewell B and Hinkley Point C operational. EDF has a programme to examine extending the operational lifespan of Sizewell B, from its current estimated closing date of 2035, to at least 2055.[59]

In May 2022, the UK generated about 15% of its electricity from nuclear compared with 25% in 1995. Some may see this as a triumph for renewables but the IEA's *Nuclear Power in a Clean Energy System* cautions: 'Despite the impressive growth of solar and wind power, the overall share of clean energy sources in total electricity supply in 2018, at 36%, was the same as it was 20 years earlier because of the decline in nuclear. Halting that slide will be vital to stepping up the pace of the decarbonisation of electricity supply.'[60] The 'IEA's Nuclear Fade Case' examines where nuclear in advanced economies may decline in the absence of investments in lifetime extensions or new build. Lifetime extensions are well worthwhile and have been agreed, or applied for, in the US.[61]

57 Roberts, T., & Clark, H. *Nuclear electricity in the UK: special feature*, p. 65. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/789655/Nuclear_electricity_in_the_UK.pdf.

58 Leggett, T. 'Extended life for two UK nuclear power stations', BBC News 9 March 2023, https://www.bbc.co.uk/news/business-64906179 . Also see ONR. 'EDF announces operating life extensions for Heysham 1 and Hartlepool', 9 March 2023, https://news.onr.org.uk/2023/03/edf-announces-operating-life-extensions-for-heysham-1-and-hartlepool/

59 EDF. 'Sizewell B starts review to extend operation by 20 years', 6 April 2022, www.edfenergy.com/media-centre/news-releases/sizewell-b-starts-review-extend-operation-20-years.

60 IEA. *Nuclear Power in a Clean Energy System*, Fuel report May 2019. This is the shorter version of the full report. www.iea.org/reports/nuclear-power-in-a-clean-energy-system.

61 WNN. 'Constellation seeks licence extensions for Illinois plants', 31 October 2022. www.world-nuclear-news.org/Articles/Constellation-seeks-licence-extensions-for-Illinoi.

From *Industrial Strategy* to *British Energy Security Strategy*

In 2017, the Government's *Industrial Strategy* White Paper identified Grand Challenges. Under 'Nuclear' it saw the sector as: 'integral to increasing productivity and driving growth.' It saw nuclear as low carbon power vital to our current and future energy mix.[62] Furthermore, the *British Energy Security Strategy: Secure, clean and affordable British Energy for the long term* (April 2022) focuses on future build with the Government planning large increases in renewables while aiming to approve a fleet of eight new reactors plus SMRs.[63] The strategy notes that nuclear supplies 15% of our electricity while it 'is the only form of reliable, low carbon electricity generation which has been proven at scale and returns more than a hundred times as much power as a solar site of the same size. We can only secure a big enough baseload of reliable power for our island by drawing on nuclear.'[64] The civil nuclear industry looks to be expanded with 24 GW by 2050 – 25% of projected electricity demand (which is likely to double today's capacity) and three times more than the current installed capacity. I am in favour of returning our nuclear capacity to 25% where it was previously.

A comprehensive strategy review by Chris Skidmore MP, *Mission Net Zero: Independent Review of Net Zero* (January 2023), reported that new nuclear power is: 'a no-regrets option' as power demand increases and current nuclear plants close. It agreed with the *British Energy Security Strategy* but stated it required more detail to ensure achievements plus nuclear deployment targets in 2035 not just 2050 to capitalise on future opportunities e.g. small modular reactors, advanced modular reactors, fusion and nuclear uses beyond the power sector. Furthermore, it recognises that new nuclear plants are a no-regrets option, even considering their upfront costs and lengthy construction periods.[65] In March 2023, the Government's two *Powering up Britain* documents explained its plans, including more nuclear, for ensuring energy security.[66] And the Gov-

62 HM Government. *Industrial Strategy: Building a Britain fit for the future*, White Paper Cm 9528, 27 November 2017, p. 206, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/730043/industrial-strategy-white-paper-print-ready-a4-version.pdf

63 HM Government. *British Energy Security Strategy: Secure, clean and affordable British Energy for the long term*, Policy paper, April 2022, pp. 20-21. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1069973/british-energy-security-strategy-print-ready.pdf.

64 *ibid*., p. 20.

65 Skidmore, C. *Mission Net Zero: Independent Review of Net Zero*, 13 January 2023, pp. 94-95. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1128689/mission-zero-independent-review.pdf. For a summary, see: Brader, C. *In Focus: Mission zero: Independent review of net zero*, House of Lords Library 20 January 2023. https://lordslibrary.parliament.uk/mission-zero-independent-review-of-net-zero/.

66 Department for Energy Security and Net Zero. 'Powering up Britain', Policy Paper last updated

ernment had classified nuclear as green.

Hinkley Point C and Sizewell C Power Stations

Currently, EDF and China General Nuclear (CGN) are building Hinkley Point C (HPC) in Somerset which has two European Pressurised Reactors (EPRs) of 1630 MWe each. HPC will supply reliable low-carbon energy to meet 7% of the country's electricity needs – enough for around six million homes. Over its 60-year lifespan it will avoid 600 million tonnes of carbon dioxide emissions – thus helping achieve Net Zero.[67] Emissions during the construction of HPC are small compared to its operation over a 60-year life. EDF and CGN's Net Zero Report states, in a comparison with burning gas, HPC 'will take just 60 days to avoid the equivalent amount of carbon dioxide released during its 10-year build.' Moreover, using 'a more sustainable cement substitute' has reduced emissions from concrete production.[68]

EDF and CGN's report *Hinkley Point C: Socio-economic Impacts Report* (2021) highlights its benefits to the local community (e.g. secure skilled jobs) and country. Furthermore, EDF commissioned an important lifetime carbon assessment for HPC by environmental specialists Ricardo Energy & Environment which was verified by engineering consultants. The study showed that HPC would be cleaner than renewables.[69] The conclusions were in line with a report from the United Nations Economic Commission for Europe (UNECE).[70] A similar life cycle analysis study by EDF on France's reactor fleet showed that the emissions were very low carbon. France's use of nuclear, with 56 operational reactors, and renewables means its electricity is 97% CO_2-free.[71] HPC unit 1 is expected to generate electricity in June 2027. With its 60-years life that will take unit 1 until 2087 and a possible lifetime extension of 20 years. What about waste? EDF explains that the large reactor core design optimises fuel usage

4 April 2023, www.gov.uk/government/publications/powering-up-britain.

67 See EDF. 'About Hinkley Point C'. www.edfenergy.com/energy/nuclear-new-build-projects/hinkley-point-c/about.

68 EDF & CGN. Hinkley Point C: Creating a positive environmental impact, November 2021, pp. 5, 8. www.edfenergy.com/sites/default/files/hinkley_point_c_-_creating_a_positive_environmental_impact._november_2021.pdf.

69 EDF. Life cycle carbon and environmental impact analysis of electricity from Hinkley Point C nuclear power plant development, ED 13018102, Final Report, Issue number 1, 26 October 2021, https://www.edfenergy.com/sites/default/files/hpc_-_life_cycle_carbon_and_environmental_impact_analysis._november_2021.pdf. Summary at: WNN. 'Hinkley Point C cleaner than renewables, study shows', 22 November 2021, https://tinyurl.com/343ps6vh.

70 UNECE. *Life Cycle Assessment of Electricity Generation Options*, 2021, www.unece.org/sites/default/files/2021-10/LCA-2.pdf.

71 WNN. 'EDF study confirms very low carbon nature of nuclear', 20 June 2022, www.world-nuclear-news.org/Articles/EDF-study-confirms-very-low-carbon-nature-of-nucle.

using less uranium and producing less long-lived radioactive wastes compared with today's water reactors. Almost a third-less long-lived radioactive wastes will be produced.[72]

Sizewell C (SZC) in East Suffolk will be a near replica of HPC. In January 2020, the UK Government committed £100 million to SZC. Then in its December 2020 Energy White Paper, it committed to a Final Investment Decision for at least one more large-scale nuclear plant, after Hinkley Point C, by December 2024. Moreover, in September 2021, 48 UK unions called for more rapid progress to be made in new nuclear build at SZC and on previously stalled projects. They also called for development of SMRs.[73] In late 2022, SZC was granted planning permission and in November 2022 the Government became a 50% partner with EDF which is expected to make a final investment decision in 2023.

Sizewell C's *Our Commitments to Britain* addresses nine commitments.[74] Under No.5 'Clean' it shows how nuclear needs a much smaller land area than wind and solar sources. Once operational, SZC will use 33 hectares of land while, to produce the same electricity, solar panels require 30,000 hectares and wind turbines 90,000 hectares. A previous comparison with land usage was made by the Campaign to Protect Rural England (CPRE) about meeting our 2050 target (then an 80% reduction in emissions). It advocated developing a sustainable energy system that did not destroy the countryside.[75]

SZC aims to go beyond electricity production and offer cogeneration in a low-carbon energy hub with opportunities for clean hydrogen production, direct air capture (DAC) of carbon dioxide and production of clean aviation fuel**.** With DAC, the captured carbon dioxide can be combined with hydrogen to make synthetic fuels. Following research and development a consortium is prepared to build a demonstration plant and foresees the full-scale plant removing 1.5 million tonnes of CO_2 per year – equivalent to almost offsetting 'the UK's entire

72 EDF. 'About Hinkley Point C: Frequently asked questions - How will you deal with the waste from Hinkley Point C?' www.edfenergy.com/energy/nuclear-new-build-projects/hinkley-point-c/about.

73 WNN. 'UK unions call for government backing of new build projects', 14 September 2021, www.world-nuclear-news.org/Articles/UK-unions-call-for-government-backing-of-new-build.

74 EDF Energy. Sizewell C: Our Commitments to Britain, 2021, p. 2. https://tinyurl.com/485c5yvw. Also YouTube video at: What is Sizewell C and what does it mean for the UK? https://www.youtube.com/watch?v=IInLLuysAR0

75 CPRE. *Warm and Green: Achievable affordable, low carbon energy while reducing impacts on the countryside*, April 2015, pp. 29-31. www.cpre.org.uk/resources/warm-and-green/. Also see: Helm, D. Green and Prosperous Land: A Blueprint for Rescuing the British Countryside (2019) www.dieterhelm.co.uk/natural-capital/environment/introduction-to-green-and-prosperous-land-a-blueprint-to-rescuing-the-british-countryside/ and his video at Introduction to Green and Prosperous Land: A Blueprint for Rescuing the British Countryside. www.dieterhelm.co.uk/natural-capital/environment/introduction-to-green-and-prosperous-land-a-blueprint-to-rescuing-the-british-countryside/

emissions from railway transport.'[76] The plant may also supply district heating.

Small modular reactors (SMRs)

The World Nuclear Association's (WNA) description of SMRs defines them as nuclear reactors: 'generally 300 MWe equivalent or less' using module factory build, series production to reduce costs and reduced construction times.[77] Nevertheless, some SMRs are larger. In *Let There Be Light!* I discussed SMRs as potential future reactors and noted that a House of Lords Science and Technology Commission, in October 2016, criticised the Government for its inaction on civil nuclear power. Since then, interest has grown internationally. Interestingly, SMRs are not entirely new as often perceived – they were developed and deployed by the US mainly for electricity and heat in the 1950s/60s in remote locations during the Cold War. Moreover, these modular reactors supplied drinking water and avoided using vast volumes of polluting diesel fuel. After use they were safely dismantled and decommissioned.[78]

On 19 January 2022, the UK parliament debated 'Small Modular Reactors and Energy Security.' Virginia Crosbie, conservative Member of Parliament for Ynys Môn (Anglesey), Wales highlighted the merits of SMRs with three principal reasons: (1) modular construction should remove previous issues with large nuclear plants, for example, financing, and long construction times, (2) they offer energy security with low-carbon energy, and (3) they provide a new industrial revolution – levelling up, high-skilled jobs and supply chains.[79]

SMRs have unique features and benefits. Rolls-Royce SMR Ltd (a consortium of companies) plans to build a fleet of 16 SMRs in the UK using small pressurised water reactors (PWRs). The design has four key elements: (1) low cost, (2) deliverable, (3) global & scalable, and (4) investable. SMRs will be built from modular units made in dedicated factory conditions before site assembly. Around 90% of the manufacturing and assembly activities will be made in these factories so producing high-quality products and reducing risks with on-site construction. The technology includes the whole nuclear power plant with: 470 MWe low-carbon electricity powering around one million homes (equivalent to over 150 onshore wind turbines and enough power for a city the size

76 WNN. '"Megatonne" CO2 capture plant plan for Sizewell C', 15 June 2022. https://tinyurl.com/2xtmv6y7.

77 WNA. 'Small Nuclear Power Reactors', updated January 2023, www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/small-nuclear-power-reactors.aspx.

78 Salisbury, M. 'The frosty history of the first SMRs ever built…in the 1950s/60s', *Nuclear Future* (2021) 17(6), 20-23.

79 UK Parliament. *Small Modular Reactors and Energy Security*, Hansard - UK Parliament debated 19 January 2022. https://hansard.parliament.uk/commons/2022-01-19/debates/D95C81CC-F4B1-420C-A53A-625A9AF82C1F/SmallModularReactorsAndEnergySecurity.

of Leeds); reliable baseload energy for at least 60 years; provision for green (clean) hydrogen production and synthetic fuels; a land footprint one-tenth of a conventional nuclear plant; factory construction of modules; thousands of regional jobs and economic benefits.[80] In April 2023, the Rolls-Royce SMR design completed Step 1 (initiation) and entered Step 2 (fundamental assessment) of the UK's Generic Design Acceptance (GDA) undertaken by the UK's independent regulators: the Office for Nuclear Regulation, the Environment Agency and Natural Resources Wales. During Step 2 people are invited to 'have their say' on the dedicated Rolls-Royce website.[81]

Nuclear fusion – a distant hope

The UK Government's *Ten Point Plan* indicates it wants to commercialise fusion energy technology and the Government issued *Towards Fusion Energy: The UK Government's Fusion Strategy* (October 2021). Further, its *Green Paper: Towards Fusion Energy* (2021) addresses a regulatory framework and introduced a consultation.[82] A commercial prototype plant is to be built at West Burton in Nottinghamshire with anticipated operation in the early 2040s.[83] This will be the Spherical Tokamak for Energy Production (STEP). So, fusion will have little impact on achieving net zero by 2050 but there are current economic benefits alongside long-term benefits of commercial viability. Nevertheless, fusion research in the US during late 2022 has shown it is possible to generate more energy than the energy put in, although scaling up from a prototype to a commercial power station is a major step.

An international perspective post-Fukushima

Readers will be aware of the international decisions that were made after the Fukushima accident, particularly the decision by Germany to phase-out its nuclear plants. However, since then there has been a resurgence of interest in

80 Rolls-Royce SMR Ltd. 'Small Modular Reactors', 2022. https://www.rolls-royce.com/innovation/small-modular-reactors.aspx#section-smr-build.

81 ONR. 'Rolls-Royce SMR', 13 April 2023. www.onr.org.uk/new-reactors/rolls-royce/index.htm. The timeline for Step 2 is until July 2024 after which the final Step 3 begins. Rolls-Royce SMR. 'Rolls-Royce SMR Generic Design Assessment (GDA)', 2023, https://gda.rolls-royce-smr.com/.

82 BEIS. *Towards Fusion Energy: The UK Government's response to the consultation on its proposals for a regulatory framework for fusion energy*, June 2022, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1084472/towards-fusion-energy-uk-government-response.pdf.

83 Roe T., & A. Smith. 'Nuclear fusion plant to be built at West Burton A power station', BBC News 3 October 2022. www.bbc.co.uk/news/uk-england-nottinghamshire-63119465.

building new nuclear plants and life extensions for operating plants, in order to achieve net zero and energy security. Extensive information is provided by the IEA's *Electricity Market Report 2023*. Here, I provide a few examples.

Some countries do not operate nuclear power plants. Greece has chosen not to build nuclear reactors because of the earthquake risk but it is working towards nuclear cooperation with Bulgaria on a long-term supply contract. Bulgaria's two reactors supply around one-third of the country's electricity but it has plans to build more.[84]

The contrasts in Europe are evident in the different decisions made by France and Germany. Nevertheless, after much discussion and debate, the EU's European Taxonomy includes nuclear (and gas) as 'green investments'.[85] The UK's religion and society think tank, Theos in *Reflections on COP26*, includes A. McIntosh's observation: 'Decarbonising energy is the biggest challenge, and even here, it is hard to do the right thing.' He notes: 'Germany chose to get rid of nuclear, but now its carbon footprint is nearly double that of neighbouring France, and the carbon intensitivity [spelling in the original] of its coal-generated electricity is nine times that of nuclear France.'[86] Further, Germany has a high dependency on gas even with all its renewable energy. After the Fukushima accident it began closing its nuclear stations with all to close by the end of 2022, but after Russia invaded Ukraine, it reviewed its position for power in the winter 2022/23. The country's three remaining nuclear plants were allowed to operate until April 2023 when they were permanently shutdown.[87]

Examples of countries that are building, or planning to build, new nuclear plants (with large reactors and SMRs) include Canada, China, the Czech Republic, Finland, France, India, Poland, Russia, South Korea, United Arab Emirates, UK, and the USA. In April 2023, Finland's latest reactor, the 1,600 MWe Olkiluoto 3 (OL3) European Pressurized Water (EPR), after very many delays, started supplying electricity, providing 15% of the country's total electricity.[88]

Finally, it is of interest to note developments in Japan. Despite the Fukushima accident, the nation recently changed its nuclear policy. The Green Trans-

84 WNN. 'Bulgaria planning for nuclear cooperation with Greece', 22 March 2022, www.world-nuclear-news.org/Articles/Bulgaria-planning-for-nuclear-cooperation-with-Gre.

85 WNN. 'European Parliament backs nuclear and gas in EU taxonomy', 6 July 2022, https://www.world-nuclear-news.org/Articles/European-Parliament-backs-nuclear-and-gas-in-EU-ta.

86 McIntosh, A. 'COP26 as a ritual space', in Pennington, M., Christie, I. (Eds.). *Reflections on COP26: What Does Theology Have to Offer the Conversation around the Climate Crisis?* Theos report 2022, p. 71. www.theosthinktank.co.uk/cmsfiles/Climate-Crisis-report.pdf.

87 WNN. 'German cabinet approves extended reactor operations', 20 October 2022, www.world-nuclear-news.org/Articles/German-cabinet-approves-extended-reactor-operation.

88 WNN. 'TVO accepts Olkiluoto EPR ahead of commercial operation', 20 April 2023, www.world-nuclear-news.org/Articles/TVO-accepts-Olkiluoto-EPR-ahead-of-commercial-oper.

formation (GX) Executive Committee has considered major changes including energy and Japan's Cabinet approved a new policy. The features include seeing nuclear power as 'a power source that contributes to energy security and has a high decarbonisation effect.' Japan will restart as many reactors as possible and extend the operating life of older ones.[89]

What about nuclear waste?

I provide a discussion on waste in chapter 6 of *Let There Be Light!* There, I noted that in the US high-level radioactive waste storage has continued since 1999 at the Waste Isolation Pilot Plant (WIPP). It is a deep underground facility, in a salt bed, for US military waste and not civil nuclear waste. But it demonstrates that high-level radioactive waste has been permanently disposed.

Bussey (see above) in his Christians in Science blog recognises the need to store radioactive waste underground for very long periods adding there is 'no compelling reason why this cannot be done.' Indeed. In Finland, the world's first deep geological disposal facility (GDF) – around 450 m underground – has already been built for civil nuclear waste and further information on this is available.[90] Further, France's national radioactive waste management agency Andra has applied to the regulator for the review of a deep repository for high-level radioactive waste, that is long-lived, and intermediate-level waste.[91]

The UK Government's progress on developing a GDF is available in the Nuclear Waste Services (NWS) report: *GDF Annual Report 2020-2021*.[92] Local communities have demonstrated an interest in hosting a GDF, so three Community Partnerships have been set up and one Working Group. And a new strategy produced by the NWS aims to make this waste 'permanently safer, sooner'.[93]

What about waste produced by SMRs? One recent study has suggested that

89 WNN. 'Cabinet approves change in Japanese nuclear policy', 10 February 2023, www.world-nuclear-news.org/Articles/Cabinet-approves-change-in-Japanese-nuclear-policy.

90 Sky News. Inside the world's first nuclear waste tomb in Finland, www.youtube.com/watch?v=0gLia6uyzBU. Also see: Nuclear Waste Services. 'NWS hosts Sky News visit to world's first GDF in Finland', 18 October 2022, www.gov.uk/government/news/nws-hosts-sky-news-visit-to-worlds-first-gdf-in-finland. Gil, L. 'Finland's Spent Fuel Repository a "Game Changer" for the Nuclear Industry, Director General Grossi Says', 26 November 2020, www.iaea.org/newscenter/news/finlands-spent-fuel-repository-a-game-changer-for-the-nuclear-industry-director-general-grossi-says.

91 WNN. 'Application for French repository accepted for review', 23 June 2023. www.world-nuclear-news.org/Articles/Application-for-French-repository-accepted-for-rev.

92 NWS. 'GDF Annual Report 2020-2021', 18 February 2022, www.gov.uk/government/publications/gdf-annual-report-2020-2021.

93 NWS. 'Nuclear Waste Services launches strategy that will make nuclear waste permanently safe, sooner' News story 25 April 2023, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1154015/NWS_CorporateStrategy_Report_2023.pdf.

waste would be increased but this study is limited to five reactor designs. Mark Shwartz's article 'Stanford-led research finds small modular reactors will exacerbate challenges of highly radioactive nuclear waste', outlines the research and its conclusion that: 'overall, small modular designs are inferior to conventional reactors with respect to radioactive waste generation, management requirements, and disposal options.'[94] However, a blog by expert Kirk Sorensen, called 'PNAS SMR waste study rebuttal' has challenged the conclusions and demonstrates deficiencies in the research.[95]

So, progress continues. What particularly concerns the author is the millions of tonnes of carbon dioxide released continually into our atmosphere and now uncontrollably 'stored' in our oceans thus affecting acidity, biodiversity and sea level rise that is, and will, impact people inhabiting small islands, coastal regions, and cities, e.g. in Bangladesh. If we love God and our neighbours then we should help, as Jesus illustrated in his parable of the Good Samaritan.

Air pollution

One of the many benefits of replacing fossil fuels with nuclear energy and renewables is improved air quality. In a 2013 report, *Prevented Mortality and Greenhouse Gas Emissions from Historical and Projected Nuclear Power*, climate scientists James E. Hansen and Pushker A. Kharecha demonstrated from historical data that using global nuclear energy instead of burning fossil fuels had 'prevented an average of 1.84 million air pollution-related deaths and 64 gigatonnes of CO_2-equivalent ($GtCO_2$-eq) greenhouse gas (GHG) emissions' and future use of nuclear would prevent further deaths.[96] Germany's switch from nuclear power to more fossil-fuelled plants means that increased local air pollution around these plants has resulted in increased deaths, as demonstrated in the December 2019 working paper *The Private and External Costs of Germany's Nuclear Phase-Out* by Stephen Jarvis, Olivier Deschenes and Akshaya Jha. They analyse annual financial costs and comment that 70% of the costs arise from '1,100 excess deaths per year resulting from the local air pollution emitted by the coal-fired power plants operating in place of the shutdown nuclear plants.'[97]

94 Shwartz, S. 'Stanford-led research finds small modular reactors will exacerbate challenges of highly radioactive nuclear waste', 30 May 2022. https://news.stanford.edu/2022/05/30/small-modular-reactors-produce-high-levels-nuclear-waste/.

95 Sorensen, K. 'PNAS SMR waste study rebuttal', Blog 1 June 2022. www.energyfromthorium.com/2022/06/01/pnas-smr-rebuttal/.

96 Kharecha, P.A., & Hansen, J.E. 'Prevented Mortality and Greenhouse Gas Emissions from Historical and Projected Nuclear Power', Environ. Sci. Technol. 2013, 47(9) 4889–4895. Also see: Hansen, J. & Pushker, P. Greens for Nuclear Energy, 2020, www.greensfornuclear.energy/james-hansen-phd-pushker-kharecha-phd/.

97 Jarvis, S., Deschenes, O., & Jha, A. *The Private and External Costs of Germany's Nuclear*

Recent research, led by Harvard University with collaboration from University College London and Leicester University, reported: 'Fossil fuel air pollution responsible for 1 in 5 deaths worldwide.' The study's authors observe that much of the debate on climate change focuses particularly on carbon dioxide emissions but they urge policy makers etc., to consider air quality and 'prevent many more millions of needless deaths.' In short, their work: 'shows that more than 8 million people around the globe die each year as a result of breathing in air containing particles from burning fuels like coal, petrol and diesel, which aggravate respiratory conditions like asthma and can lead to lung cancer, coronary heart disease, strokes and early death.' This is often an unrecognised high risk requiring swift action.[98] Wood burning stoves too contribute to air pollution.

In Ontario (Canada) electricity generation in 2019 comprised: nuclear (61%), hydro (24.5%), wind (7.4%), gas (6.4%), biofuel (0.45%) and solar (0.25%). So, more than 90% of electricity supplied was from 'non-emitting sources', for example, nuclear and hydro plus some renewables (wind and solar). Refurbished nuclear plants helped remove coal from its mix from 2014. Moreover, Bruce Power's nuclear units provide 'flexible, dynamic capability.' Emission intensity (measured as gCO2e/kWh) from the electricity sector shows that Ontario emits less GHGs than California and much less than Germany (almost 10 times higher than Ontario despite high investments in renewables). Ontario has cut emissions and has low-cost electricity for its consumers. Moreover, improved air quality limits 'emergency room visits, illness and hospital admissions, resulting in a financial benefit of $2.6 billion annually.'[99]

The value of nuclear in reducing air pollution remains largely unrecognised. Also largely unrecognised are the medical benefits provided by large reactors and research reactors in the production of radioactive sources for use in radiotherapy cancer treatments, sterilisation of medical equipment, and radioisotopes for diagnosis and treatments.

Conclusions

This paper provides an evidence-based overview of nuclear energy's place in achieving net zero and national security. It focuses on challenging, complex areas and the crucial role of electricity production and cogeneration. It is a plea

Phase-Out, National Bureau of Economic Research, December 2019, p. 31, https://nber.org/system/files/working_papers/w26598/w26598.pdf.

98 'Fossil fuel air pollution responsible for 1 in 5 deaths worldwide'. UCL News, University College London, 9 February 2021, www.ucl.ac.uk/news/2021/feb/fossil-fuel-air-pollution-responsible-1-5-deaths-worldwide.

99 BrucePower. *The Ontario Energy Report*, 2019, pp. 3, 10. www.brucepower.com/wp-content/uploads/2020/01/2020_OntarioEnergyReport-1.pdf.

for understanding, wisdom and love in action while not remaining silent on climate change solutions. Nuclear power is not solely about technology but importantly about our planet and people including those working in the industry and supply chains, Christians, and non-Christians alike. These people should be respected in honest conversations, treated as loved by God and invited to speak so that others can benefit from their firsthand experience while also listening to evidence-based arguments on nuclear energy's merits. Many Christian leaders may lack qualifications and understanding in science and technology but it is essential that Christian churches and organisations endeavour to link science, faith, and the environment in an objective assessment of the relative merits and risks of firm, clean, and low-carbon nuclear power in order to guide and equip their congregations. However, we can cope with challenging circumstances in hope. Indeed, early Christians lived in a very different and difficult context – the Roman Empire – where their leader Jesus had been crucified but they boldly proclaimed his resurrection and eternal life.

Robert S Dutch was a scientist/engineer in the nuclear power industry and holds a classics-theology PhD. He wrote *Let There Be Light! Nuclear Energy: A Christian Case.*