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Monitored this issue:

A global picture of industrial interdependencies between civil and military nuclear infrastructures

Nuclear Monitor #804 in May 2015 included a detailed critique of the many ways nuclear advocates trivialise and deny the connections between nuclear power (and the broader nuclear fuel cycle) and weapons proliferation. Since then, the arguments have been turned upside down with prominent industry insiders and lobbyists openly acknowledging power-weapons connections.

This remarkable about-turn has clear origins in the crisis facing nuclear power and the perceived need to secure increased subsidies to prevent reactors closing and to build new ones. For background on these developments, see Nuclear Monitor #865 ('Nuclear lobbyist Michael Shellenberger learns to love the bomb'), #858 (''Pro-nuclear environmentalists' in denial about power/weapons connections'), #855 ('The myth of proliferation-resistant nuclear power'), #850 ('Nuclear power, weapons and 'national security''), and #849 ('James Hansen's Generation IV nuclear fallacies and fantasies').

Much of the discussion about interconnections between the civil nuclear industry and weapons proliferation focuses on the production of fissile material, in particular plutonium and highly-enriched uranium. Another set of important interconnections receive much less attention: industrial supply chains involving the wider nuclear skills, education, research, design, engineering and industrial capabilities.

These 'industrial interdependencies' are discussed in detail in this issue of *Nuclear Monitor*. The paper – written by Andy Stirling and Phil Johnstone and published in August 2018 as a University of Sussex Science Policy Research Unit Working Paper (www.sussex.ac.uk/spru/research/swps) – is an extended, updated and more fully referenced version of a chapter appearing in the *World Nuclear Industry Status Report 2018* (www.worldnuclearreport.org).

Thanks to Andy and Phil for their tireless work over many years drawing attention to the military dimensions of the peaceful atom, and for allowing us to print their important paper here.

A global picture of industrial interdependencies between civil and military nuclear infrastructures

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Contents:

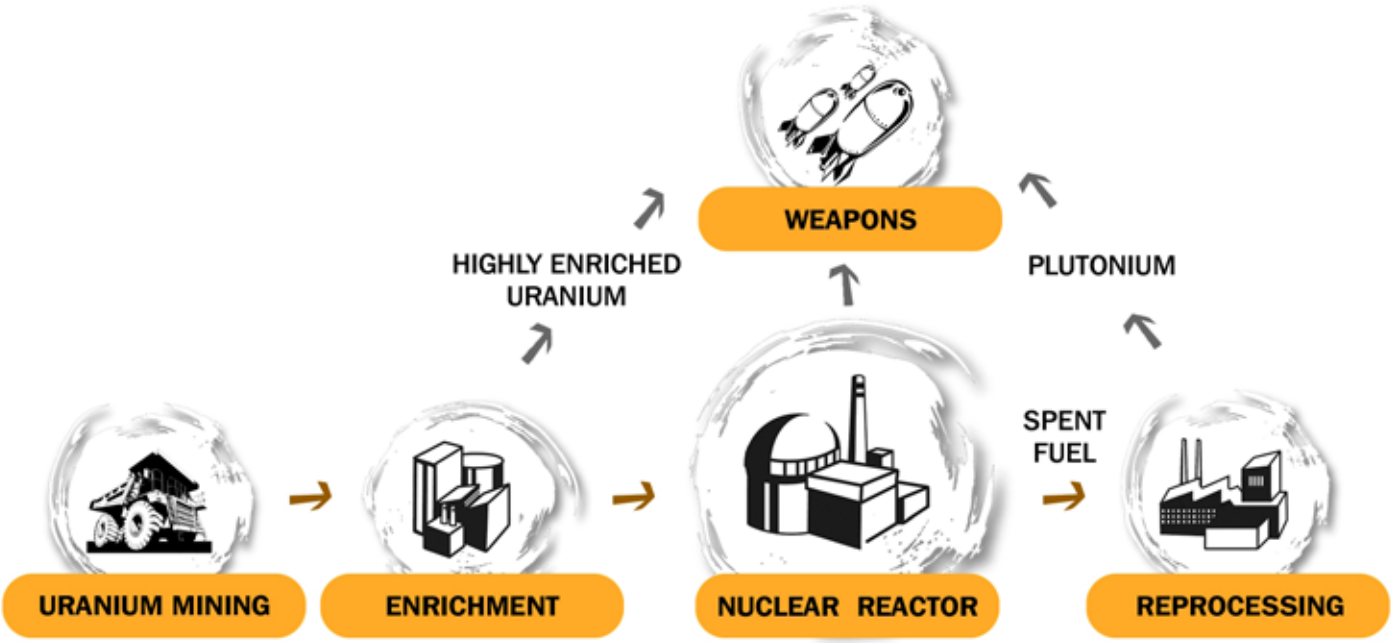
Abstract

Noting the increasingly unfavourable economic and operational position of nuclear power around the world, this paper reviews evidence for a hitherto neglected connection between international commitments to civil and military nuclear infrastructures. Reviewing well established understandings of interlinkages associated with fissile materials and other nuclear weapons related substances, the paper surveys a distinct – and currently potentially more important – kind of interdependency that has up to now received virtually no policy attention. This relates to the national industrial supply chains necessary for the manufacture and operation of nuclear propelled submarines, that are deemed central to strategic military doctrine in a few states – and to burgeoning ambitions in a number of others. One of the most striking features of these interdependencies, is that evidence is so strong in strategic military literatures, but that the issue is typically so neglected in energy policy analysis. So the repercussions extend beyond specific domains of civil and military nuclear policy making in themselves – significant as these may be. Across a range of countries, arguably the most important implications arise for the rigour and transparency of mainstream academic and energy policy analysis and the quality and accountability of wider democratic processes – that are failing to give due attention to the evident force of these connections. With civil nuclear power now increasingly recognised to be growing obsolescent as a low carbon energy source, but key military capabilities evidently depending so strongly on its maintenance, a potentially important new window of opportunity may be opening up for robust measures to reduce global military nuclear threats.

1: The Odd Persistence of Nuclear Power

Why is it that nuclear power is proving so surprisingly resistant in particular places around the world, to dramatically changing global energy market conditions and structures for electricity supply?[1] Against a backdrop of stark decline in the worldwide nuclear industry as a whole, plans for plant life-extension and nuclear new-build remain major areas of investment in a few specific countries.[2] Intense attachments persist to projects like Hinkley Point C in the UK[3] for instance, despite: a delay standing presently at more than a decade; costs multiplying fivefold over original estimates; a series of still-unresolved serious technical difficulties; and demands for escalating government financial concessions and guarantee.[4] Globally, a range of different commentaries show how the relatively small number of continuing nuclear programmes typically display a similar mix of severely deteriorating conditions and oddly dogged enthusiasm.[5]

It is surprising to see such persistent nuclear attachments, because nuclear energy has clearly become much less attractive, when compared with competing low-carbon options. Worldwide, nuclear is already significantly more expensive than major alternatives like solar photovoltaics and onshore and offshore wind power, with the disadvantage growing fast.[6] Available cost-effective energy resources from these renewables are huge,[7] and their modularity, small unit size and short lead times typically make them a more rapid means to carbon emissions abatement.[8] Where once nuclear advocates claimed that 'firm' (inflexibly-steady) nuclear output is an advantage, grid operators now recognize that



new network technologies render the underlying idea of 'base load' power to be "*outdated*".[9] Many options exist to manage so-called intermittent power[10] at a fraction of the growing renewable cost advantage.[11]

Other stated energy policy aims also favour renewables. Across different countries, these are typically domestic resources whose geographically-distributed nature helps avoid the particular vulnerabilities associated with concentrated sites and sources as well as insecure global fuel supply chains.[12] Amidst many complexities, renewables offer employment benefits generally greater than those of nuclear.[13] And capital intensity, large unit size and long lead times are also major financial downsides of established nuclear designs in current investment markets.[14] Technologies with such strikingly cumulative comparative disadvantages as nuclear would be abandoned in most other sectors. Therefore, serious questions arise as to why the declared commitments of some governments (like those of the UK, USA, Russia, Saudi Arabia, Turkey and Iran) should remain so oddly intense around a nuclear option that under-performs so badly across so many energy policy criteria.

The oddity is compounded by the fact that change is so routine – and rapid – in other areas of the global electricity sector. Electricity markets have shifted radically in several waves of reform.[15] Emerging distributed networked infrastructures are unrecognizable from only a few years ago. Over decades, many other supply technologies have come and gone. New forms of integrated gasification, pebble bed combustion and combined cycle gas turbines have been adopted.[16] Battery and other storage technologies have been transformed.[17] In many places, once-dominant fossil fuel infrastructures are now being phased out.[18] Globally, renewables attract greater capital investment than all other generating technologies put together.[19] With nuclear power comprising only relatively small proportions of most electricity systems, it is not clear why it should evidently be more 'locked in' than anything else. So, the question remains: why is it proving so difficult in particular places, to acknowledge the generally growing obsolescence of nuclear power?[20]

2: Neglected Military Dimensions of Nuclear Power

In a diverse and complex world, there are obviously many factors at work. In policy imaginations, organisational attitudes and elite cultures as well as infrastructures, the importance of sheer momentum and inertia should never be underestimated.[21] Although now increasingly replaced by the iconic status of other areas of innovation (like machine intelligence, synthetic biology, neuroscience and nanotechnology) one possible reason for the persistence of nuclear power in particular settings may relate to a residual effect of the past image of nuclear expertise as an epitome of scientific and technological prowess – and so a symbol of national standing.[22] And it must also be acknowledged that under some legitimate political perspectives, a few of the general strategic disadvantages discussed here around nuclear power are less acute in specific geographical settings. But the overall picture is so stark, that there do remain good grounds for asking what other influences might be in play, to help maintain such entrenched support for an energy technology that is, in so many respects, increasingly superseded.

In particular, questions arise over many well-documented military entanglements of nuclear power. A range of costly specialist international legal-political regimes is dedicated to addressing these unique features of nuclear power.[23] Nuclear reactors, whether small or commercial-size, are the only effective means to produce crucial fissile materials for nuclear weapons, like plutonium-239. The fuel supply chain for nuclear power, and uranium enrichment in particular, is the main source for other weapons ingredients like high-enriched uranium. Further specialist materials for various types of thermonuclear weapons, like tritium, are by-products of nuclear power. All these 'material links' have been acknowledged for many years and described in great detail.[24] But less well appreciated in public debate, are a set of 'industrial interdependencies' – involving the wider nuclear skills, education, research, design, engineering and industrial capabilities associated with civil nuclear industries, that are also essential in many ways to the sustaining or introduction of nuclear weapons programmes or their associated platforms and infrastructures.[25]

Together, these material links and industrial interdependencies have left many important imprints on the world civil nuclear industry. For instance, most reactor design traditions derive from past prioritization of military aims. Heavy water reactors and graphite-moderated designs like the Chernobyl-style RBMK or the French and UK natural uranium gas-graphite reactors were based on principles originally chosen to facilitate on-load refueling for production of plutonium required in nuclear weapons manufacture. Likewise, even the most modern variants of light water reactors are still built around basic engineering principles originally optimized for the confined spaces of nuclear-propelled submarines.[26] Yet, even after many decades of opportunities to establish entirely new designs dedicated to civilian power production, these military-derived variants still account for almost all of global civil nuclear power capacity worldwide.[27] In fact, there exists no major commercial reactor design, whose basic configuration was optimized from first principles solely for safe or economic civilian power. A high proportion of leading designs for a currently much-vaunted 'new generation' of Small Modular Reactors or SMRs relate even more closely to contemporary nuclear submarine propulsion reactors.[28]

Nor is there any sign that these longstanding connections are diminishing. An additional dimension to civil-military nuclear interdependencies has only come to light only in recent years. This is the importance to government support of nuclear power in some countries of continuing commitments to build and maintain military, nuclear-propelled submarines.[29] These machines are often identified as being among the most complex and demanding manufactured artefacts ever conceived. Security concerns are seen to require the sustaining of the entire range of necessary industrial capacities within a single country. Only in the last couple of years, are inside sources beginning to acknowledge that even in large economies like that of the USA, it is difficult to sustain this military capability without a parallel civil nuclear power industry.[30] High profile documents by industry bodies and senior policy figures openly urge that perceived needs to maintain the naval nuclear propulsion industry is a major reason to continue with otherwise-declining civil nuclear power.[31] National achievement of nuclear submarine capabilities is also widely associated with global strategic leadership, for instance with former President Dilma Rousseff of Brazil stating in 2014 on a visit to the new Brazilian nuclear submarine facility: "The Brazilian naval force… have contributed decisively to our nation, towards our country integrating into the select group of five member countries of the Council of the United Nations Security dominating the submarine construction technology with nuclear propulsion".[32]

There are, around the world, then, many major connections between civil and military nuclear industrial capabilities, skills, expertise and infrastructures. Yet when taken together, these joint civil-military nuclear specialisms are in their turn, in many ways arguably unusually restricted in their general interconnectedness throughout the economy.[33] Dependencies between civil and military nuclear are often greater than between nuclear-specific engineering and other industrial sectors. So, if civilian nuclear power and its associated specialist practices are to be allowed (like many earlier technologies) to go obsolete, then – with more net employment typically available in proportion to investment by other means[34] – it seems that the only significant losers would be the nuclear establishments of a small number of countries that maintain *military* nuclear ambitions. Conversely, for those hoping for long-stalled reversal in either horizontal or vertical nuclear weapons proliferation[35], it is possible that obsolescence of civil nuclear power as an energy source forms a potentially major – but under-considered – global opportunity.

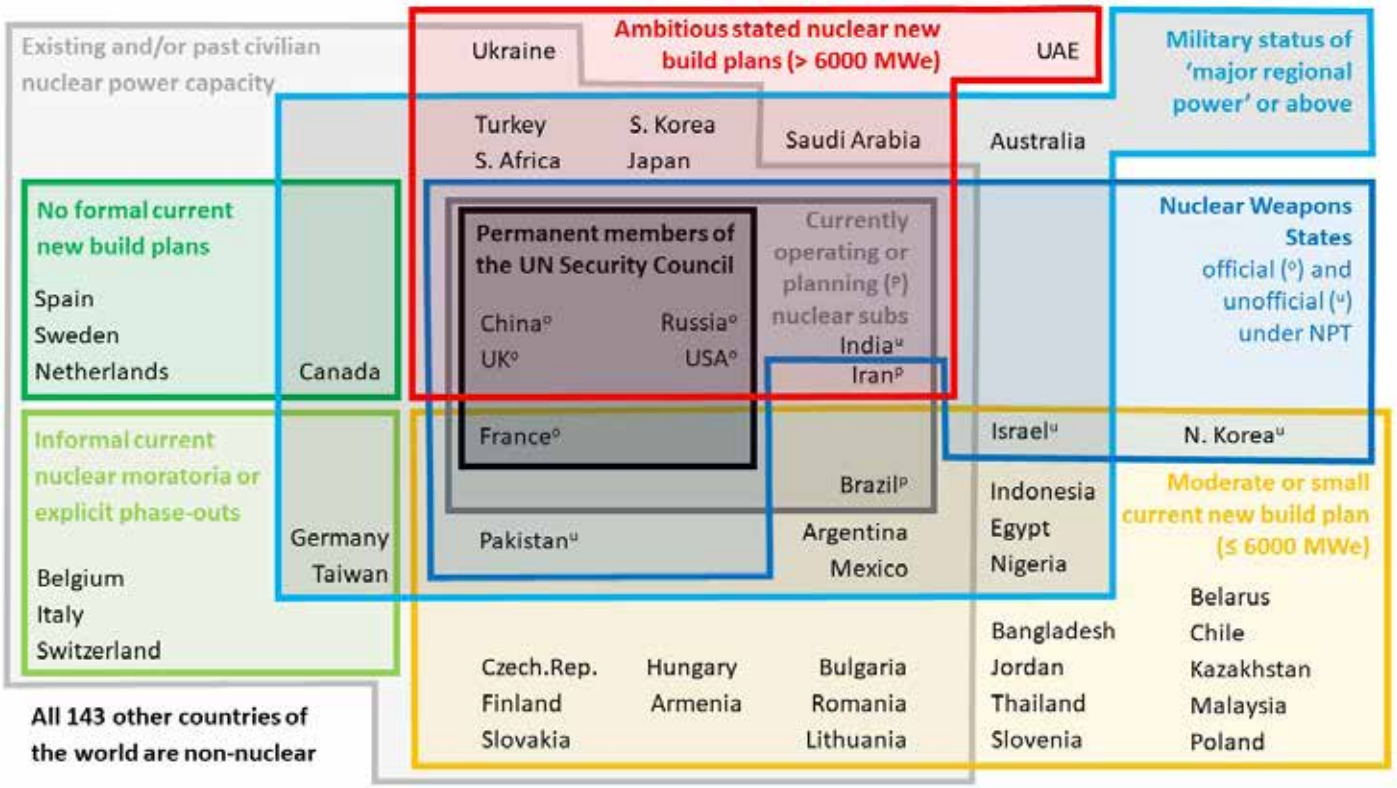
3: Broad Patterns in National Civil and Military Nuclear Ambitions

In all states with current and past nuclear weapons capabilities, parallel availability of the skills and industrial and research capacities now associated with civil nuclear power have been essential.[36] The revenues arising from nuclear electricity sales have also been important, as part of these flow indirectly into supply chains and research, training and industrial systems that have joint civil and military applications.[37] Some states (notably Israel and North Korea) have built modest military nuclear capabilities without directly pursuing civil nuclear power. But even here, existence of wider international nuclear industries (especially in sponsoring powers) has remained crucial.[38] More broadly in current global nuclear politics, it is generally recognized that the intensity and nature of many national nuclear programmes is best understood by reference to ambitions to establish industrial capacities, by means of which future acquisition of military nuclear capabilities would be relatively easy.

This is true historically for instance, in countries like Canada, Germany, Sweden and Switzerland, which were all enthusiastic pioneers of civil nuclear power, who also entertained early nuclear military ambitions, but which each later relinquished nuclear weapons. And these linkages can also be found in the history of ostensibly civilian nuclear programmes of currently non-nuclear weapons states including Argentina, Bangladesh, Brazil, Japan, South Africa and South Korea. Likewise, such links are well acknowledged in contemporary politics around the projected nuclear programmes of Egypt, Iran, Saudi Arabia, Turkey and the United Arab Emirates. The *Economist* for instance, argues of Saudi Arabia's potential nuclear new-build programme, that it makes "little economic sense".[39] The Saudi King has put this directly into a military context, in stating that "without a doubt, if Iran developed a nuclear bomb, we will follow suit as soon as possible".[40] Civil nuclear programmes in Egypt, Turkey and the United Arab Emirates, are held to be among the countries "most poised to seek advanced nuclear capabilities in response to a resurgent nuclear Iran".[41]

One rough circumstantial reflection of these evident general civil-military nuclear connections can be seen in the coarse-grain structure of resonating nuclear and military enthusiasms around the world today. Figure 1 below illuminates broad overlapping patterns across all relevant countries, between general military standing, nuclear weapons status, nuclear submarine capabilities, global geopolitical profile and the intensity of declared civil nuclear ambitions (as expressed in data published by the leading nuclear industrial advocacy organization).

Figure 1: Circumstantial Relationships Between Reported Civil Nuclear Ambitions and Different Categories of International Military and Geopolitical Status (civil nuclear plans are based on WNA data)[42]



According to the positions asserted in national data published by the global industry trade body – the World Nuclear Association (WNA), the five largest-scale prospective nuclear new-build programmes in the world are in four of the five 'official' nuclear weapons states (excepting France).[43] India and Iran are also pursuing ambitious nuclear new-build programmes. And France is an illuminating exception, in that the scale of its existing reliance on nuclear power in itself militates against further large-scale national expansion. So large is the existing French civil nuclear fleet, that the associated national engineering base also required for military purposes is much less under threat from nuclear decline than in other countries. But the *Le Monde* newspaper nonetheless does still highlight "the ultimate question an expert dares asking": "What would become of the credibility of our nuclear weapons programme and our position at the UN [Security Council], if France were to renounce its [nuclear power] plants?"[44]

Such military anxieties over declining capabilities seem even more pronounced in other nuclear-armed countries with proportionally less well-established nuclear industries. The major state-held Russian nuclear construction and services company Rosatom is clear that the "[r] eliable provision of Russia's defense capability is the main priority of the nuclear industry".[45] And in the US, the *Nuclear Energy Institute,* now strongly lobbies for subsidies for failing nuclear developments, on the grounds that abandonment of these will "stunt development of the nation's defense nuclear complex".[46] Likewise, the pro-nuclear *Environmental Progress* group, highlights the national security implications of the USA's declining nuclear industry.[47] Perhaps most significantly, former US Energy Secretary Ernest Moniz[48] launched a report in 2017, which stated that "a strong domestic supply chain is needed to provide for nuclear Navy requirements. This supply chain has an inherent and very strong overlap with the commercial nuclear energy".[49] Accordingly, a memorandum leaked under the Trump administration in June 2018, reveals that recent regulatory measures to protect nuclear power are a reflection of high-level perceptions that the civil nuclear industry is essential to national security, specifically including naval propulsion.[50]

Also evident in Figure 1 is a pattern under which, of the relatively few other countries in the world presenting themselves as pursuing the most ambitious civil nuclear new-build plans, eleven out of thirteen hold the status of being major (at least regional) military powers.[51] With regard to the next tier of stated national ambitions for nuclear power, an association between civil nuclear and military interests is also apparent. Of 23 countries widely designated as 'major regional powers' or above, only Australia has never developed, or is not seeking to develop, a civil nuclear programme. And among those in this group who have developed such programmes in the past, only Germany and Taiwan are presented by the WNA to be without any nuclear new-build programmes.[52]

Given the complexities of global affairs, it must be expected that any general pattern like this will include exceptions. That the UAE is the only example in the world of a country displaying high stated civil nuclear ambitions that is not at least a regional military power, is actually an indication of the striking nature of the broader patterns shown in Figure 1. And it is notable in this regard, that the UAE is also at the geographical centre of what is currently one of the most intense areas of regional military tension – and whose stated ambitious nuclear plans are in any case somewhat performative. Likewise, North Korea is already a nuclear-armed state, which is not formally categorized as a regional military power. But this involves other well-known extraordinary circumstances, implicating arguably the single most acute military nuclear stand-off in the contemporary world. On the other hand, Germany is the only regional military power which WNA acknowledges to be actively scaling back its civil nuclear programmes. Yet this is also a special case, in that the '*Energiewende*' policy in Germany has been forced by globally distinctive social mobilization.[53] In Japan, the current reigning back of plans for nuclear power is conditioned by the even more unique political consequences of the Fukushima catastrophe, but is not reflected in WNA projections.[54] And here, civil-military links are also still alive, for instance, in senior Liberal Democrat politician Shigeru Ishiba's statement that "Japan should never let go of nuclear power plants. Because having nuclear power means that we can manufacture nuclear weapons within a certain period of time and it can be a deterrent".[55]

Albeit circumstantial, it is quite obvious that it tends to be the leading global military powers who are also the leaders in civil nuclear power around the world – and the most committed to large scale new nuclear build. There is no global or regional military power that has not displayed at least some active history of strong strategic pressures to pursue civil nuclear power capabilities. Conversely, no country with a current nuclear moratorium or that is phasing out nuclear power has either nuclear weapons, nuclear submarines or plans to develop either.

4: The Case of the UK

The UK was one of the first developers of both nuclear weapons and commercial nuclear power. With early civil nuclear facilities documented to have been central to military plutonium production[56], joint civil-military nuclear ambitions are especially relevant in the UK. Military nuclear standing is frequently emphasized as being central to elite British political identities on the world stage:[57] suggestive of the cherished status of a country that "punches above its weight";[58] and indirectly linked to the "seat at the top table" of permanent membership of the UN Security Council.[59]

So, it is no surprise that the UK should currently be home to some of the most intense nuclear rhetorics – defying the manifest serious global decline of nuclear power by: loudly championing a "nuclear renaissance"; pursuing declared nuclear new-build commitments that are exceptional in Europe (and in proportion to its system, the largest in the world); and with the then-responsible minister insisting in 2016 that "nuclear power is what this Government is all about for the next twenty years".[60]

Yet the depths of these idiosyncrasies have not gone unnoticed, even by UK governmental bodies. The UK Parliament's National Audit Office (NAO), for instance, concluded in a 2017 report that government nuclear planning "… has locked consumers into a risky and expensive project with uncertain strategic and economic benefits".[61] The NAO holds Government justification of this programme to hinge on "wider strategic" considerations beyond the officially-stated "energy trilemma" around affordability, climate change and energy security. Neither the NAO nor any other government body anywhere disclose what these other "unquantified strategic benefits" actually are.[62]

It is long since the UK undertook any kind of full policy analysis systematically to justify its nuclear commitments. Here, the NAO again departs from normal procedure by explicitly criticizing in 2017 that Government, in its review of the proposed Hinkley Point C project, "has not formally reviewed and consulted on its published strategic case for nuclear power since the publication of the 2008 white paper".[63] And, in addition, this last attempt to justify the current nuclear programme was itself based on a consultation process that was successfully challenged by judicial review for being too cursory.[64] This earlier white paper was also repeatedly criticized by Parliament at the time for being inappropriately opaque.[65]

Thus, the most recent major UK energy policy initiative that was not subject to this kind of general formal skepticism goes back even further, to 2003. And, based on a far more comprehensive analysis[66], the conclusion of this last fully-considered UK Government energy white paper was that nuclear power is "unattractive".[67] Openly unwelcome to the then Prime Minister Tony Blair[68] (but for reasons that were undeclared), it was this finding that was over-ridden by the cursory white paper of 2008 in a process acknowledged by Parliamentarians[69] and nuclear proponents[70] alike, to have been extraordinarily secretive. And despite the market conditions becoming even less favourable, it is this under-substantiated positive official characterization of nuclear power that persists to this day.

A question that arises unusually explicitly and specifically in the UK case, then, is what these powerful but hidden "strategic factors" might be, that have so emphatically trumped stated energy policy considerations? Again, the NAO quietly cast some light on this, observing in their 2008 report on the UK Trident nuclear weapons programme that "[o]ne assumption of the future deterrent programme is that the United Kingdom submarine industry will be sustainable and that the costs of supporting it will not fall directly on the future deterrent programme".[71]

If the costs of keeping the national submarine industry in business must fall elsewhere, what could that other budget be? With successive NAO reports being so thorough in their documenting of strategic justifications for different flows of resources, there is one explanation that is notably consistent with both NAO's 2008 Trident and 2017 Hinkley Point reports. This is, that the oddly-unspecified "unquantified strategic benefits" that the NAO observed in 2017 to be driving UK Government support for otherwise uneconomic civil nuclear power, relates directly to the military nuclear submarine capabilities that they assumed in 2008 to be underwritten from other sources.[72]

This NAO evidence is only the tip of the iceberg. These official statements by the UK's leading public audit body confirm a picture that is highly visible in defense debates, but remarkably undiscussed in energy policy. With heavily redacted documents released under freedom of information legislation expressing strong anxieties[73], a host of other defense policy discussions are very clear that the UK nuclear 'submarine industrial base' would not be sustainable, if a decision were taken to discontinue civil nuclear power.[74] Indeed, statements from UK submarine industry sources note incentives to "mask" the costs of this military programme behind the related civilian industrial infrastructure.[75] Submarine reactor manufacturer Rolls Royce recently dedicated a major report in large part to the argument that a programme of submarine-derived small modular reactors should be adopted in UK energy policy in order to "relieve the Ministry of the burden of developing and retaining skills and capability" on the military side.[76]

These civil-military links are also highly visible in UK industrial strategy, with priority given to a nuclear 'sector deal' spanning both sectors together[77] and with many new agencies and programmes openly dedicated to achieving synergies between UK submarine and civil nuclear programmes. The nuclear sector deal is particularly focused on facilitating 'mobility' between the civil and defense nuclear workforce as a key strategy to manage the skills challenge. It is stated in "The Nuclear Sector Deal"[78] that "the sector is committed to increasing the opportunities for transferability between civil and defense industries and generally increasing mobility to ensure resources are positioned at required locations" and

that 18 percent of projected skills gaps can be met by 'transferability and mobility'. The document also states that the skills gap can be met through "greater alignment of the civil and defense sectors with increased proactive two-way transfer of people and knowledge. As the military service sector tends to be age and nationality limited, we propose that we actively seek a recognisable career pathway between the civil and defence sectors to ease transfer between the two".

The "Nuclear Skills Strategic Plan" outlines: "Demand for competent people is forecast to rise from 78,000 full time equivalent people (FTEs) in 2015 to 111,000 by 2021, requiring a total industry inflow of 9,000 per year" which includes both civil and defense activities. Precise numbers on defense requirements are not given in latest skills documentation and important caveats are required. One is that it is acknowledged that "in the civil sector, the new-build programme means that the main challenge is in the 'generic skills' element. For research and development, the challenge is more located in the area of subject matter experts". While generic skills are not specific to nuclear, the defense industry has more requirement for nuclear-specific skills in the long term. Also the analysis of future skills "averages across the industry and will not reflect movement within the industry".[79]

This recent emphasis on mobility came after earlier statements on the severe crisis in the nuclear submarine industry.[80] As stated by Grimes et al: "Across the enterprise the availability of deep specialist expertise in key and suitably qualified staff appears to be at the bare minimum necessary to deliver the programme".[81] There are additional pressures on the defense nuclear programme as most workers have to be British nationals for security reasons and for cuts MoD budgets contribute to pressures on the submarine industry.[82]

These included acknowledgements of overlaps and shared skills between defense and civil and the benefits of civil engagement for defense, as illustrated by Rolls Royce: "Skills are considered to be transferable between military propulsion and civil programmes", where "a larger involvement in the broader [civil] industry will also have a spillover benefit to military capability through skill development and experience exchange[83] as well as admissions that the decline of civil nuclear has exacerbated skills challenges related to defense.[84]

As acknowledged by the UK submarine industry lobby organization, the Keep Our Future Afloat campaign (KOFAC), "the decline of the UK civil nuclear programme has forced the military nuclear programme, and in particular the nuclear submarine programme, to develop and fund its own expertise and personnel in order to remain operational".[85] Additionally, in terms of R&D support, it has been noted that "the MOD's programme had been underwritten by civil nuclear research that has over the years been dismantled and commercialised", where the "… expertise these activities generated has atrophied".[86]

Grimes et al, are providing specific recommendations for managing the capabilities crisis in the nuclear submarine industry through further engagement with the civil sector. This includes that "the programme seek imaginative methods to better engage with the emergent civil new-build programme on nuclear matters to the benefit of Defence", that "the Research Programme Group establish a workstrand to look at leveraging to maximum effect civil nuclear investment", and that "MOD revisit the possible option of utilising other nuclear facilities including those in the civil sector".[87]

Stephen Lovegrove, current Permanent Secretary at the Ministry of Defense and former Permanent Secretary at the Department for Energy and Climate Change responsible for negotiating the Hinkley Point C contracts, stated under questioning by the U.K. Parliament Public Accounts Committee[88]: "We are completing the build of the nuclear submarines, which carry conventional weaponry. We have at some point to renew the warheads, so there is very definitely an opportunity here for the nation to grasp in terms of building up its nuclear skills. I do not think that that is going to happen by accident; it is going to require concerted Government action to make it happen."[89]

It is these remarkable conjunctions that have helped lead to reports in the UK[90] and international[91] press, that what is underway in the UK is, in effect, an unacknowledged cross-subsidy (amounting at least to several tens of billions of pounds)[92] away from electricity consumers and to the benefit of military nuclear interests. Whatever the actual figures may prove to be amidst many complexities and uncertainties, the *prima facie* evidence seems clear that future UK electricity prices are being raised significantly higher than would otherwise be the case, at least partly in order indirectly to support military nuclear infrastructures by enabling a flow of resources into joint civil-military nuclear engineering supply chains and wider shared provisions for nuclear skills, research, design and regulation.

The attraction of this strategy for the UK Government appears to lie in the triple aim of: (1) finding a means to cover the otherwise insupportable costs of this major military commitment; (2) whilst keeping the resulting expenditures away from inconvenient public scrutiny; and (3) entirely off the public books. But what is perhaps most remarkable, is that these evidently powerful pressures with apparently major impacts, remain entirely undiscussed anywhere in UK energy policy or related media debates. Despite the very high financial stakes, it is perhaps these implications for the rigour, transparency and accountability of UK democracy that are therefore most important. And where other countries – like those reviewed earlier – display similar dynamics, similarly serious implications evidently also arise elsewhere in the world.

5: Nuclear Power, Nuclear Weapons and Democracy

Despite complexities, ambiguities and uncertainties – as well as constant change – the picture painted in this paper is quite striking. Based on a broad survey of the international scene (and with a particular focus on the UK), a diverse array of evidence has been summarised, that there exist continuing major links between deeply entrenched commitments in particular settings to civil and military nuclear technologies. A strong general association can be observed across different countries, between strategic military ambitions and the scale of stated plans for new nuclear power. In the USA, powerful imperatives have recently been openly declared in high level policy debate, to maintain support for otherwise-uncompetitive nuclear power in order to sustain a continuing nuclear navy. In the UK, evidence for the same links is strong on the military side, but virtually entirely absent in official energy policy documents or debate. Official audit procedures seem aware of these issues, but are circumspect about discussing them in public. And for their part, industry sources are clear about incentives to 'mask' these links.

So, equally in terms of institutional processes, as well as energy outcomes, the economic and political stakes are clearly very high. Nuclear power is a controversial and expensive technology with a number of adverse wider characteristics, that is increasingly recognized to be growing obsolete by comparison with competing low-carbon energy technologies, yet which continues to receive oddly intense (and very expensive) continuing strong government support in several places around the world. The reasons for this are seriously under-documented and under-scrutinized in energy policy arenas. But it is relatively clear in policy debates that civil and military commitments are interlinked. Given the volume, depth and ostensible rigour of detailed energy analysis around the world, this substantive gap in discussion is quite remarkable. That so much of the picture has to be indirectly inferred – rather than being openly queried and analysed in policy documents – adds to, rather than detracts from, the gravity of the issue.

It is especially notable that official energy policy discussions should be so silent on these issues, in countries like the UK, which pride themselves on robust policy procedures and vigorous democratic debate.[93] It took more than a year from the first coverage in major newspapers in other countries, for the topic even to be raised in a UK broadsheet (in two major pieces in *the Guardian*). Yet, despite the strong qualitative evidence reviewed in this paper, analysis of interdependencies, cross-subsidization and strategic complementarities between civil nuclear power and the military sector (especially the nuclear submarine industries), remains undiscussed beyond the work of the present authors – with even the asking of questions being dismissed by other energy researchers as a 'conspiracy theory'.[94] Firm quantitative evidence for the scale of such interdependencies does indeed remain lacking. But this is because necessary disaggregated information on flows of revenue, capital, employment and skill are not in the public domain. It may be that the gravity of these political implications – and fear of 'conspiracy theory' accusations – may in themselves be helping to inhibit due attention. So the undermining effects of these pressures on democratic debate are among the most serious potential impacts of the continuing policy and media inertia on these questions.

In the end, however, the issues raised in this analysis are quite straightforward. To whatever degree, there can be little doubt that the increasingly precarious global status of civil nuclear power is presenting a growing problem for the small minority of the world's countries who wish to pursue military nuclear ambitions. Yet the secretive nature of the forces at work is evidently helping prevent definitive conclusions over the scale of the associated impacts on military or energy strategies. What is urgently required in order to resolve this picture more clearly, then, is the publication of currently missing crucial data concerning the nature and scale of the flows and interdependencies between civil and military nuclear industries, and a rigorous process of scrutiny involving probing interrogation, dedicated research and robust analysis.

A series of questions remain open. To what extent are current continuing commitments to nuclear power, in particular countries around the world, due to national attachments to parallel military nuclear infrastructures? What is the magnitude of public provision for a shared civil and military strategic base in education, skills, research and key industrial and supply-chain capabilities? How much of the costs of these shared underpinnings for military nuclear ambitions are being concealed by otherwise uneconomic joint civil-military nuclear infrastructures? How much cheaper might low carbon electricity services be to consumers if these military pressures for nuclear lock-in were removed, easing a shift to more affordable energy efficiency and renewable energy? And if this lock-in is escaped, what opportunities are presented by the current demise of nuclear power, towards also reducing global exposures to military nuclear threats?

It is remarkable that queries like these have for so long remained so unattended to in worldwide energy debates.[95] For answers to be so lacking – and even the questioning itself to be so muted – is arguably one of the most serious legacies of the uniquely-shared infrastructures, institutions and cultures of civil and military nuclear technologies. What seems at stake is not just the future of these interlinked energy and security strategies, but arguably the health of democracies themselves.

Notes & References

1. For an early picture of this dynamic, see for example: Lovins, Amory B., L. Hunter Lovins, and Leonard Ross. 1980. Nu-clear Power and Nuclear Bombs. Foreign Affairs, or Steve Thomas, *The Realities of Nuclear Power: International Economic and Regulatory Experience* (Cambridge: Cambridge University Press, 1988). See also: Steve Thomas, "Competitive energy markets and nuclear power: Can we have both, do we want either?" Energy Policy, September 2010, see http://www.provedor.nuca.ie.ufrj.br/eletrobras/estudos/thomas1.pdf, accessed 17 June 2018.

2. Ample evidence of this are also provided in successive editions of the World Nuclear Industry Status Report, available here: https://www.worldnuclearreport.org/

3. With a UK Government Chief Scientist asserting in the national press, for instance, that "we have no alternative to nuclear power: if there were other sources of low carbon energy I would be in favour, but there aren't" David King, "David King: Why We Have No Alternative to Nuclear Power: If There Were Other Sources of Low Carbon Energy I Would Be in Favour, but There Aren't," *The Independent Online*, 13 July 2006, see http://www.independent.co.uk/voices/commentators/david-king-why-we-have-no-alternative-to-nuclear-power-5329750.html, accessed 1 July 2014

4. Holly Watt, "Hinkley Point: The 'dreadful Deal' behind the World's Most Expensive Power Plant," *The Guardian Online*, 21 December 2017, see https://www.theguardian.com/news/2017/dec/21/hinkley-point-c-dreadful-deal-behind-worlds-most-expensive-power-plant, accessed 21 December 2017

5. Schneider et al. 2017. World Nuclear Industry Status Report.

6. In the U.K., for instance, this is recognized by numerous official analyses undertaken concurrently with the intense expressions of commitment to nuclear power cited above, e.g. National Audit Office, "Nuclear Power in the UK", 13 July 2016 see https://www.nao.org.uk/wp-content/uploads/2016/07/Nuclear-power-in-the-UK.pdf, accessed 13 July 2016. Among (energy) economists, there is a general consensus that nuclear power has never been economical, and the detailed survey by Lucas W. Davis . 2012. "Prospects for Nuclear Power." Journal of Economic Perspectives 26 (1): 49–66. https://doi.org/10.1257/jep.26.1.49.

7. IRENA, "Renewable Power Generation Costs in 2017", January 2018.

8. Ged Davis & José Goldemberg, eds. "*Global Energy Assessment: Toward a Sustainable Future*", Cambridge University Press, 2012.

9. Karel Beckman, "Head of UK's National Grid Says 'Idea of Large Power Stations for Baseload Is Outdated,'" *Renewable Economy*, 2015.

10. All power sources, including nuclear power, are to some extent subject to unanticipated fluctuations or interruptions in output. All are vulnerable to unplanned shutdowns, or need periodically to be withdrawn from service for maintenance, repair, refueling, or for other safety or security related reasons. The overall rate of availability of nuclear power plants is about two thirds only, and unexpected outages are very considerable, see Stefan Seifert, et al., (2017): Are Outages Homogeneous Among Nuclear Reactor Technologies? Evidence from Machine Learning Approaches. DIW Berlin, Working Paper.

11. For instance the U.K. regulatory body OFGEM quotes the U.K. Energy Research Council (UKERC) when stating in their own 2017 report that "at these levels, the UK Energy Research Centre (UKERC) estimates that integration costs are between £5 per MWh and £10 per MWh of intermittent energy (up to £478 million in 2016)", in OFGEM, "State of the Energy Market Report", 2017, see https://www.ofgem.gov.uk/system/files/docs/2017/10/state_of_the_market_report_2017_web_1.pdf, accessed 25 January 2018.

12. Indeed, it is striking that a number of features that distinguish nuclear power from other electricity supply sources, also fall among characteristics rated in national security strategies (e.g.: HM Government. *A Strong Britain in an Age of Uncertainty: The National Security Strategy*. Stationary Office, 2010) to count as some of the most grave "tier one" national security threats – namely: potential for very large scale industrial accidents; iconic targets for physical terrorism or cyber attack; and possible infrastructure contexts for international military crises (Stirling, A. Nuclear Threats. *Guardian*, 15 November 2010. Available here: https://www.theguardian.com/environment/2010/nov/15/nuclear-threats-terrorism-civil-infrastructure).

13. A report by the Renewable Energy Association (REA) in the UK highlighted that there are over 125,940 people employed in the renewable energy sector in the UK; see REA "The Authorative Annual Report On the UK Energy Sector", 24 July 2017, see http://www.r-e-a.net/upload/final_low_res_renewable_energy_view_-_review_2017.pdf, accessed 24 July 2017. The UK nuclear sector is said to currently employ 65,000 people with industry estimates that 40,000 new jobs would be created through a new-build program; see World Nuclear News, "UK Civil Nuclear Job Count Rises by 2000," 4 September 2016, see http://www.world-nuclear-news.org/C-UK-civil-nuclear-job-count-rises-by-2000-1409164.html. However a report in 2014 for the Office for National Statistics found that in terms of direct jobs, there are 15,000 direct jobs in nuclear power and 43, 500 direct jobs in the renewables sector; Office for National Statistics, "UK Environmental Accounts: Low Carbon and Renewable Energy Economy Survey - Office for National Statistics, 31 January 2016, see https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/finalestimates/2016 ONS Statistical Bulletin", accessed 1 May 2018.

14. Ged Davis & José Goldemberg, eds. *Global Energy Assessment: Toward a Sustainable Future*. (Cambridge University Press, 2012)

15. Steve Thomas, "Competitive energy markets and nuclear power: Can we have both, do we want either?" *Energy Policy*, September 2010, see http://www.provedor.nuca.ie.ufrj.br/eletrobras/estudos/thomas1.pdf, accessed 17 June 2018; Joe Barnes, "Japanese Energy Security and Changing Global Energy Markets: An Analysis of Northeast Asian Energy Cooperation and Japan's Evolving Leadership Role in the Region" *James A Baker III Institute for Public Policy*, 1 May 2000, see https://www.bakerinstitute.org/media/files/Research/31659dc4/japanese-energy-security-and-changing-global-energy-markets-an-analysis-of-northeast-asian-energy-cooperation-and-japans-evolving-leadership-role-in-the-region.pdf; IEA. "World Energy Outlook 2014: How will global energy markets evolve to 2040?" *International Energy Agency,* 2014, see https://www.iea.org/publications/freepublications/publication/WEO2014.pdf.

16. IEA. World Energy Outlook 2010. (2010). Available at: https://www.iea.org/publications/freepublications/publication/weo2010.pdf

17. Noah Kittner, Felix Lill et al, "Energy storage deployment and innovation for the clean energy transition." *Nature,* 31 July 2017, see https://www.nature.com/articles/nenergy2017125; POST. Energy Storage. Energy, briefing by the UK Parliamentary Office for Science and Technology, House of Commons, London, 2009, available at: http://researchbriefings.parliament.uk/ResearchBriefing/Summary/POST-PN-492. See also: William F. Pickard, "Addressing the Intermittency Challenge: Massive Energy Storage in a Sustainable Future." *Proceedings of the IEEE,* February 2012, see https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6132597, accessed 17 June 2018.

18. Craig Morris, & Arne Jungjohann, *Energy democracy: Germany's Energiewende to renewables*. (Palgrave, 2016); Jürgen-FriedrichHake, Woolfgang Fischer et al. "The German Energiewende - History and status quo." *Energy*,1 December 2015, see https://www.sciencedirect.com/science/article/pii/S0360544215004594, accessed 17 June 2018; Karoline Rogge, Phil Johnstone, "Exploring the role of phase-out policies for low-carbon energy transitions: The case of the German Energiewende." *Energy Res. Soc. Sci*., November 2017, see https://www.sciencedirect.com/science/article/pii/S2214629617303316, accessed 17 June 2018; Sebastian Strunz, "The German energy transition as a regime shift.", *Ecol. Econ*, April 2014, see https://www.sciencedirect.com/science/article/pii/S0921800914000342, accessed 17 June 2018.

19. Frankfurt School-UNEP, "Global Trends in Renewable Energy Investment 2016" Frankfurt School of Finance and Management GmbH, 2016, see http://fs-unep-centre.org/sites/default/files/publications/globaltrendsinrenewableenergyinvestment2016lowres_0.pdf, accessed 2 January 2017.

20. Robin Cowan, "Nuclear Power Reactors: A Study in Technological Lock-In," *Journal of Economic History*, September 1990, see http://dimetic.dime-eu.org/dimetic_files/cowan1990.pdf, accessed 17 June 2018.

21. Shiela Jasanoff and Sang-Hyun Kim, "Containing the Atom: Sociotechnical Imaginaries and Nuclear Power in the United States and South Korea," *Minerva* 47, 26 June 2009, see https://link.springer.com/article/10.1007/s11024-009-9124-4, accessed 17 June 2018.

22. See: Gabrielle Hecht, *The Radiance of France: nuclear power and national identity after World War II*, 2009, MIT Press. Some additional comparative implications across technologies around this point are addressed in Andy Stirling, Towards innovation democracy? Participation, responsibility and precaution in the politics of science and technology, chapter in in Annual Report of the Government Chief Scientific Adviser 2014, *Innovation: Managing Risk, Not Avoiding It. Evidence and Case Studies*, London: Government Office of Science (London: Government Office for Science, 2014), 49-62, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/381905/14-1190a-innovation-managing-risk-report.pdf

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24. Mutually complementary sources summarising diverse aspects of this material (from different perspectives, with extensive onward references to large wider literatures) include: Fischer, D. Nuclear Non-proliferation: the Prospects for the Non-Proliferation Regime after the Gulf War. *Energy Policy*, (1992); Rioux, J.-F., ed. *Limiting the Proliferation of Weapons: the role of supply side strategies*. (Carleton University Press, 1992); Black-branch, J. L. & Fleck, D., eds. *Nuclear Non-Proliferation in International Law* (Springer, 2014); Maerli, M. B. & Lodgaard, S., eds. *Nuclear Proliferation and International Security*. (Routledge, 2007); Davis, Z. S. & Davis, Z. S. The Realist Nuclear Regime. *Secur. Stud*., 2, 3–4 (1993); Edwards, R. *Nuclear Power and Nuclear Weapons: the deadly connection*. (Campaign for Nuclear Disarmament, 1985); Patterson, W. C. *The Plutonium Business and the spread of the bomb*. (Paladin, 1984).

25. John F. Schank, Jessie Riposo et al. “The United Kingdom’s Submarine Industrial Base Volume 1: Sustaining Design and Production Resources” *RAND Corporation*, 2005, see https://www.rand.org/content/dam/rand/pubs/monographs/2005/RAND_MG326.1.pdf, accessed 18 June 2018.; John F. Schank, Mark V. Arena et al “Sustaining US Nuclear Submarine Design Capabilities”, *RAND Corporation*; 2007, see https://www.rand.org/content/dam/rand/pubs/monographs/2007/RAND_MG608.pdf, accessed 17 June 2018; NSSG, “Nuclear Skills Strategic Plan” *Nuclear Skills Strategy Group*, December 2016, see http://www.cogentskills.com/media/76258/national-nuclear-skills-strategic-plan.pdf, accessed 17 June 2018; HM Government, “Sustaining Our Nuclear Skills”, *Her Majesty’s Government,* 2015, see https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/415427/Sustaining_Our_Nuclear_Skills_FINAL.PDF, accessed June 17 2018.

26. Cowan, “Nuclear Power Reactors: A Study in Technological Lock-In.”September 1990, see http://dimetic.dime-eu.org/dimetic_files/cowan1990.pdf, accessed 17 June 2018.

27. There exists no major currently widely-adopted commercial reactor design, whose basic configuration was optimized from first principles solely for safe or economic civilian power. So, this forced adaptation of military design priorities has led to requirements for additional expensive (potentially unreliable) in-depth back-up safety systems. And problems presented by irradiated fuels, reactor decommissioning and other nuclear waste arisings are also all more intractable than they otherwise might be. Despite the advantages of large-scale strategic support on security grounds, then – especially in the early stages – it seems that being such a favored military offspring has in some ways been a curse for civil nuclear power.

28. WNA, “Small Nuclear Power Reactors.” *World Nuclear Association*, May 2018, see http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/small-nuclear-power-reactors.aspx, accessed 17 June 2018; Oxford Economics. “The economic benefit of improving the UK’s nuclear supply chain capabilities.” *Oxford Economics Institute*, March 2013, see http://namrc.co.uk/wp-content/uploads/2013/04/economic-benefits.pdf, accessed 31 May 2016.

29. The stealth, range, speed and endurance of nuclear-propelled ballistic missile submarines (SSBNs) has led them to become central to the strategic military doctrines of all five formally-recognized nuclear weapons states (U.S., Russia, U.K., France and China) as well as an unofficial nuclear weapons state, India. The necessity to maintain national nuclear submarine industries in business in between the ‘drumbeat’ of orders for these SSBNs, has helped lead all of these countries also to maintain in deployment a number of expensive nuclear-propelled fleet submarines (not armed with ballistic missiles). See Gavin Ireland, “Beyond Artful: Government and Industry Roles in Britain’s Future Submarine Design, Build and Support”, Royal United Services Institute, March 2007, see https://rusi.org/sites/default/files/200706_whr_beyond_artful.pdf, accessed 17 June 2018.

    Other major regional powers are also in various stages of acquiring nuclear submarine capabilities, including Iran, Brazil and Argentina.

30. Energy Futures Initiative, 2017. “The US Nuclear Energy Enterprise: A Key National Security Enabler” August 2017, see https://static1.squarespace.com/static/58ec123cb3db2bd94e057628/t/5992f7e0bf629ad8f9d575ec/1502803938248/EFI+Nuclear+Report+FINAL+08.2017.pdf, accessed 24 June 2018.

31. [anon]. ‘Addendum’ [Leaked draft confidential memorandum with Attorney-Client Privilege], 2018; see https://www.eenews.net/assets/2018/06/01/document_gw_01.pdf, accessed 17 June 2018.

32. Defesa Aérea & Naval (in Portuguese), “Com a presença da Presidente, Marinha do Brasil inaugura prédio principal do Estaleiro de Construção de Submarinos”, 2014, see http://www.defesaaereanaval.com.br/com-a-presenca-da-presidente-marinha-do-brasil-inaugura-predio-principal-do-estaleiro-de-construcao-de-submarinos/, accessed 17 June 2018.

33. Where nuclear-related technologies are applied in other sectors (like medical uses, fire detection, weld inspection, food preservation or seed production), the scales and natures of the engineering and production infrastructures involved are of very different orders of magnitude to those associated with nuclear power. A range of alternative options are also typically available for isotope production (like linear accelerators) or substitution of key materials or equipment (as in photoelectric smoke detectors) that either entirely avoid or fall far short of full-fledged civil or military fissile materials production or large-scale industrial nuclear engineering infrastructures. See, for example: Jan Willem van Gelder, Anniek Herder, “Alternatives for the production of medical isotopes”, *Greenpeace,* 30 March 2010, see https://www.profundo.nl/download/greenpeace100330, accessed 17 June 2018; David Nusbaum, “Smashing Atoms for Peace: Using Linear Accelerators to Produce Medical Isotopes without Highly Enriched Uranium” Harvard Kennedy School Belfer Centre, October 2013, see https://www.belfercenter.org/sites/default/files/files/publication/smashingatomsforpeace.pdf, accessed 17 June 2018; George M. Moore & Miles A. Pomper, “Permanent Risk Reduction: A Roadmap for Replacing High-Risk Radioactive Sources and Materials”, James Martin Center for Nonproliferation Studies, July 2015, see https://www.nonproliferation.org/wp-content/uploads/2015/07/Pomper-Moore-2015.pdf, accessed 17 June 2018.

34. See footnote 13 for employment data for renewables and nuclear power in the UK.

35. Horizontal proliferation is the spread of nuclear weapons, materials, facilities or knowledge to countries that have not yet developed nuclear weapons. Vertical proliferation can be defined as increasing the nuclear weapon stockpiles or capabilities in a state that is already possessing nuclear weapons.

36. This is true, for instance, of the nuclear weapons and military nuclear propulsion capabilities of all the major nuclear-armed states: China, France, Russia, the U.K. and the U.S. In the very first stages of the global nuclear industry, the extraordinary circumstances of World War II and the early Cold War led to huge industrial efforts dedicated to military aims. But with rapid deployment of the first nuclear power reactors, infrastructures for uranium enrichment and spent fuel reprocessing quickly became shared between civil and military industries (economists have called this phenomenon “economics of scope”, see von Hirschhausen, Christian (2017): Nuclear Power in the Twenty-First Century: An Assessment (Part I). Berlin, DIW Discussion Paper 1700. In countries developing military weapons capabilities at a later stage, like India and Pakistan, active development of a shared civil-military national base in general nuclear skills and expertise featured even more strongly. Although in the latter case of Pakistan, an operating national civil nuclear programme has not yet eventuated, strategic reliance is significant on just such a programme in China.

37. This interlinkage has been clearly demonstrated in a very direct sense, for instance, in the U.K., where reactor designs were adopted for civilian electricity production that also facilitated production of fissile plutonium for military purposes and were operated this way by civilian utilities for many years, with plutonium diverted to weapons use (cf. David Lowry, “Military secrets of our nuclear power plants”, Guardian, 27 December 2017, see https://www.theguardian.com/uk-news/2017/dec/27/military-secrets-of-our-nuclear-power-plants. The earliest civilian reactors adopted in France were of a similar design.

38. This is the case in a strict sense, only in North Korea and Israel. But the very close relationships of each of these countries with powerful nuclear-armed patrons (with an active civil nuclear infrastructure – in China and France and the U.S. respectively) shows how international joint civil-military infrastructures remain essential.

39. The Economist, “How a Saudi Nuclear Reactor Could Accelerate an Arms Race,” *The Economist Online* (London, February 2018), https://www.economist.com/news/middle-east-and-africa/21736575-kingdoms-nuclear-ambitions-make-little-economic-sense-how-saudi-nuclear.

40. CBS News, “Saudi Crown Price: If Iran develops nuclear bomb, so will we” *CBS News Online,* 15 March 2018, see https://www.cbsnews.com/news/saudi-crown-prince-mohammed-bin-salman-iran-nuclear-bomb-saudi-arabia/, accessed 17 June 2018.

41. Sarah Burkard, Erica Wenig et al, “Nuclear Infrastructure and Proliferation Risks of the United Arab Emirates, Turkey, and Egypt”, Institute for Science and International Security, 25 August 2017, see http://isis-online.org/isis-reports/detail/nuclear-infrastructure-and-proliferation-risks-of-the-united-arab-emirates/ Washington, 2017, accessed 17 June 2018.

42. Since the object of interest here are ‘declared nuclear ambitions’, rather than ‘realistically deliverable plans’, WNA is the appropriate source. Data for formally stated nuclear ambitions are from WNA, “Nuclear Power in the World Today – 2018”, June 2018, see http://www.world-nuclear.org/information-library/facts-and-figures/world-nuclear-power-reactors-and-uranium-requireme.aspx, accessed 28 June 2018. The allocations of countries to categories in this picture are based entirely on this WNA data with no modifications to reflect alternative views. Where a detailed WNA country report conflicts with the summary table, it is the more detailed data that is used here. Data for regional military power status are from Detlef Nolte, “How to compare regional powers: analytical concepts and research topics”, Review of International Studies, October 2010, see https://www.giga-hamburg.de/sites/default/files/publications/how_to_compare.pdf, accessed 17 June 2018.

43. The five largest declared nuclear new-build programmes published by the WNA in 2017 were as follows: China 233 GWe; Russia 53 GWe; India 47.9 GWe; U.S. 33.1 GWe; U.K. 17.9 GWe, corresponding to five of the world’s six major nuclear weapons powers. WNA, “Nuclear Power in the World Today”, April 2018, see http://www.world-nuclear.org/information-library/current-and-future-generation/nuclear-power-in-the-world-today.aspx, accessed 27 July 2018.

44. Hean-Michel Bezat, “Nucléaire : Pourquoi La France Persiste,” *Le Monde*, July 2017, https://prepaecocarnot.files.wordpress.com/2017/08/nucleaire_en_france_le_monde_juillet_2017.pdf.

45. Rosatom, “Росатом Полностью Выполнил Государственный Оборонный Заказ 2017 Года,” *Https://Ria.Ru*, accessed April 15, 2018, https://ria.ru/defense_safety/20171225/1511650489.html?inj=1.

46. Amy Harder, “Nuclear scramble on tax credits”, Axios News Service, 2017. Available at: https://www.axios.com/nuclear-scramble-on-tax-credits-1513303038-7c4178f7-f93a-4614-bb13-efbca70c4835.html, accessed 27 July 2018.

47. Michael Shellenberger, “Nuclear Industry Must Change — Or Die” *Environmental Progress Website*, 17 February 2017, see http://environmentalprogress.org/big-news/2017/2/16/nuclear-must-change-or-die, accessed 12 March 2018.

48. Ernest Moniz is former United States Secretary of Energy serving under President Barack Obama from 2013-2017.

49. A longstanding nuclear advocate (Moniz, Ernest. 2011. “Why We Still Need Nuclear Power.” *Foreign Affairs* 90 (6):83–94), Moniz did not publicly discuss this particular until he launched the 2011 Energy Futures Initiative in 2017: “The US Nuclear Energy Enterprise: A Key National Security Enabler”, Washington DC, see https://static1.squarespace.com/static/58ec123cb3db2bd94e057628/t/5992f7e0bf629ad8f9d575ec/1502803938248/EFI+Nuclear+Report+FINAL+08.2017.pdf. This report is associated with former U.S. Energy Secretary Ernest Moniz, for instance by the industry and financial news agency Bloomberg: Ari Natter, “Nuclear Power’s Woes Imperil U.S. National Security, Moniz Says”, Bloomberg, 15 August 2017, see https://www.bloomberg.com/news/articles/2017-08-15/nuclear-power-s-woes-imperil-u-s-national-security-moniz-says accessed 20 August 2017.

50. [anon]. ‘Addendum’ [Leaked draft confidential memorandum with Attorney-Client Privilege]. (2018). Dowloaded (17/6/18) from: https://www.eenews.net/assets/2018/06/01/document_gw_01.pdf

51. The exception is the Ukraine, a case which is also made exceptional by a situation of armed proxy conflict with the powerful nuclear-armed neighbor Russia. In other cases, active tension with already nuclear-armed antagonists is also often a factor. This is true of India (which also maintains nuclear submarine capabilities). Abhijit Singh, “Why India Needs Both Nuclear and Conventional Submarines,” *The Diplomat* (Global, May 2016), http://thediplomat.com/2016/05/why-india-needs-both-nuclear-and-conventional-submarines/.

52. Of course, it must be cautioned again that this association is often more a reflection of formally-declared interests rather than of credible substantive plans. As documented repeatedly in the WNISR, the enthusiastically-declared nuclear projections of many countries often turn out to be little more than performative aspirations. But even just as a rhetorical association in some cases, the above pattern remains relevant as a reflection of high level policy attitudes around the world.

53. Craig Morris, Arne Jungjohann, “*Energy democracy: Germany’s Energiewende to renewables”*, Palgrave, 2016.

54. And in any case, both Germany and Japan are countries, where ostensibly civil nuclear infrastructures were developed in highly uneconomic ways that historically brought national infrastructures to the brink of weapons production capability in a context of threat by major nuclear-armed neighbors. Indeed, it has been noted, how this need for a civil industry as a base for military power is still being asserted in Japan. The only other remaining exception at this lower level of the pattern in Figure 3.1 is Taiwan, which is a regional military power with no civil nuclear new-build plans. But, like Germany and Japan, Taiwan also has a strong history of nuclear commitment in the past.

55. Quoted in 半歩前へ, “核兵器製造技術は「抑止力につながる」と石破茂！,” *Http://Www.Asyura2.Com*, 2017, http://www.asyura2.com/17/senkyo235/msg/873.html.

56. As discussed in Lorna Arnold, *Britain and the H-Bomb*, (Palgrave, 2001).

57. See https://www.telegraph.co.uk/news/uknews//12155420/Former-Labour--chief-George-Robertson-warns-Jeremy-Corbyn-not-to-scrap-Trident.html, accessed 13 February 2016.

58. Patrick Cockburn, “Patrick Cockburn: Why Must Britain Always Try to ‘Punch above Her Weight’?,” *The Independent*, July 2011, http://www.independent.co.uk/voices/commentators/patrick-cockburn-why-must-britain-always-try-to-punch-above-her-weight-2314908.html.

59. Patrick Barckham and Richard Norton-Taylor, “Trident: Deadly – and Very, Very Expensive,” *The Guardian Online*, May 2010, https://www.theguardian.com/uk/2010/may/20/trident-submarine-coalition-government-scrap.

60. BBC Radio 4, The Today Programme Interview with Amber Rudd”, *BBC Radio 4 Today Programme,* 23 March 2016, see https://www.youtube.com/watch?v=_tsBkVjRllg, accessed 17 June 2018.

61. NAO. “Hinkley C”, *National Audit Office,* 23 June 2017, see https://www.nao.org.uk/wp-content/uploads/2017/06/Hinkley-Point-C.pdf, accessed 23 June 2017.

62. NAO. “Hinkley C”, *National Audit Office,* 23 June 2017, see https://www.nao.org.uk/wp-content/uploads/2017/06/Hinkley-Point-C.pdf, accessed 23 June 2017.

63. P.19, NAO. “Hinkley C”, *National Audit Office,* 23 June 2017, see https://www.nao.org.uk/wp-content/uploads/2017/06/Hinkley-Point-C.pdf, accessed 23 June 2017.

64. High Court judge Jeremy Sullivan described the Government’s nuclear consultation at this time as “flawed”, “misleading” and “procedurally unfair”; http://news.bbc.co.uk/1/hi/uk_politics/6364281.stm, accessed 17 June 2018.

65. The Environmental Audit Committee outlined that “the Government has failed to clarify the nature of the review” and that “…the manner in which it is being conducted appears far less structured and transparent than the process by which the [2003] White Paper itself was reached”; Environmental Audit Committee, “Keeping the lights on: nuclear, renewables, and climate change”, 28 March 2006, see https://publications.parliament.uk/pa/cm200506/cmselect/cmenvaud/584/584i.pdf, accessed 17 June 2018.

66. Before the 2003 White Paper, the UK Government Performance Innovation Unit (PIU) undertook an especially substantial review and consultation in *The Energy Review.* Unusually constituted by a process of recruiting the best available independent energy expertise as well as seconded high-level civil servants – and independent also from traditional positions taken within the incumbent energy ministry – the PIU came to similar conclusions to the later White Paper, concluding on page 5 that: "the immediate priorities of energy policy are likely to be most cost-effectively served by promoting energy efficiency and expanding the role of renewables"; PIU, "The energy review", Performance Innovation Unit, February 2002, see http://www.gci.org.uk/Documents/TheEnergyReview.pdf, accessed 17 June 2018.

67. As stated on page 44 of the DTI White Paper, "Although nuclear power produces no carbon dioxide, its current economics make new nuclear build an unattractive option and there are important issues of nuclear waste to be resolved. Against this background, we conclude it is right to concentrate our efforts on energy efficiency and renewables"*;* DTI, "Our Energy Future: Creating a Low Carbon Economy" (London, 2003).

68. The Guardian, "Blair accused of energy 'greenwash'", see https://www.theguardian.com/environment/2003/feb/24/energy.greenpolitics, accessed 17 June 2018.

69. The U.K. Parliamentary Environmental Audit Committee outlined that "the Government has failed to clarify the nature of the review" and that "…the manner in which it is being conducted appears far less structured and transparent than the process by which the [2003] White Paper itself was reached". Environmental Audit Committee, "Keeping the lights on: nuclear, renewables, and climate change", 28 March 2006, see https://publications.parliament.uk/pa/cm200506/cmselect/cmenvaud/584/584i.pdf, accessed 17 June 2018.

70. Nuclear advocate Simon Taylor notes the "secrecy" in which the second energy review took place "behind closed doors", with a secret working group within Tony Blair's cabinet office, which many in the cabinet office itself were not aware of; Simon Taylor, 2016 The fall and rise of nuclear power in Britain, Cambridge: UIT Cambridge.

71. Section 5.3 page 7; of https://www.nao.org.uk/wp-content/uploads/2008/11/07081115.pdf, accessed 17 June 2018.

72. These "unquantified strategic benefits" are acknowledged in the 2017 NAO report on Hinkley Point C to extend beyond the officially-stated "energy trilemma" around affordability, climate change and energy security. Yet neither here nor anywhere else do the NAO or any other government body anywhere disclose what these other "unquantified strategic benefits" actually are. Andy Stirling, Phil Johnstone, " Some Queries over Neglected Strategic Factors in Public Accounting for U.K. Nuclear Power: evidence to the House of Commons Public Accounts Committee Inquiry on Hinkley Point C", 25 September 2017, see http://data.parliament.uk/writtenevidence/committeeevidence.svc/evidencedocument/public-accounts-committee/hinkley-point-c/written/70983.pdf, accessed 17 June 2018.

73. R Grimes, S Ion, and A Sherry, *RN Nuclear Reactor Test Facility Review* (London: Ministry of Defence, 2014).

74. House of Commons Defence Committee, "The Future of the UK's Strategic Nuclear Deterrent: the strategic context", 30 June 2006, see https://publications.parliament.uk/pa/cm200506/cmselect/cmdfence/986/986.pdf, accessed 17 June 2018.

75. Gavin Ireland, "Beyond Artful: Government and Industry Roles in Britain's Future Submarine Design, Build and Support", Royal United Services Institute, March 2007, see https://rusi.org/sites/default/files/200706_whr_beyond_artful.pdf, accessed 17 June 2018.

76. Rolls Royce, "UK SMR : A National Endeavour" (Derby, 2017), https://www.rolls-royce.com/~/media/Files/R/Rolls-Royce/documents/customers/nuclear/a-national-endeavour.pdf.

77. NIC, "The Nuclear Sector Deal Nuclear Industry Council Proposals to Government for a Sector Deal", Nuclear Industry Council, 7 December 2017, see https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/665473/The_Nuclear_Sector_Deal_171206.pdf, accessed 7 December 2017.

78. See page 36 of "The Nuclear Sector Deal" (op. cit, above).

79. NSSG, "Nuclear Skills Strategic Plan", Nuclear Skills Strategy Group, December 2016, see http://www.cogentskills.com/media/76258/national-nuclear-skills-strategic-plan.pdf, accessed 17 June 2018. Earlier reports highlight specific future requirements of both civil and defense. In the Nuclear Energy Skills Alliance *Workforce Assessment* in 2014, it is outlined that the annual forecast required recruitment per year for defense as being 1,090 up until 2021. This report also provides figures on the numbers employed in civil and defense: "Operations (including generation), decommissioning and fuel processing directly employs around 20,000 workers at some 30 sites across the U.K. Around half of those are based at Sellafield… employs a further 20,000 with around 4,500 within the Royal Navy." NESA, "Nuclear Workforce Assessment" 2014, see http://130.88.20.21/uknuclear/pdfs/NESA_Nuclear_Workforce_Assessment_2014.pdf, accessed 17 June 2018.

80. In the heavily redacted document of 2014 by Grimes et al. Specific recommendations are given for managing the capabilities crisis in the nuclear submarine industry through further engagement with the civil sector. This includes that "the programme seek imaginative methods to better engage with the emergent civil new build programme on nuclear matters to the benefit of Defence", that "the Research Programme Group establish a workstrand to look at leveraging to maximum effect civil nuclear investment" and that "MOD revisit the possible option of utilising other nuclear facilities including those in the civil sector" Robin Grimes et al, "Royal Navy Nuclear Reactor Test Facility Review" Ministry of Defence, 28 October 2014, see https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/658328/2016-03111.pdf, accessed 17 June 2018.

81. Robin Grimes et al, op.cit.

82. Robin Grimes et al, op.cit.

83. Rolls Royce in EV472, Innovation, Universities, Science and Skills Committee. 2009. "Engineering the future: turning ideas into reality: oral and written evidence", 18 March 2009, see https://publications.parliament.uk/pa/cm200809/cmselect/cmdius/50/50ii.pdf, accessed 17 June 2018.

84. As acknowledged by the Keep Our Future Afloat campaign (KOFAC) "The decline of the UK civil nuclear programme has forced the military nuclear programme, and in particular the nuclear submarine programme, to develop and fund its own expertise and personnel in order to remain operational". EV109. House of Commons North West Regional Committee, "The Future of the Nuclear Industry in the North West: oral and written evidence", 9 March 2010, see https://publications.parliament.uk/pa/cm200910/cmselect/cmnwest/361/361.pdf, accessed 17 June 2018. Additionally, in terms of R&D support it has been noted that "the MOD's programme had been underwritten by civil nuclear research that has over the years been dismantled and commercialised" where the "… expertise these activities generated has atrophied"; Robin Grimes et al, "Royal Navy Nuclear Reactor Test Facility Review" Ministry of Defence, 28 October 2014.

85. KOFAC in EV109, House of Commons North West Regional Committee, "The Future of the Nuclear Industry in the North West: oral and written evidence", 9 March 2010, see https://publications.parliament.uk/pa/cm200910/cmselect/cmnwest/361/361.pdf, accessed 17 June 2018.

86. Robin Grimes et al, op.cit.

87. Robin Grimes et al, op.cit.

88. The statement was issued in response to a submission by Andy Stirling, Phil Johnstone, "Some Queries over Neglected Strategic Factors in Public Accounting for UK Nuclear Power: evidence to the House of Commons Public Accounts Committee Inquiry on Hinkley Point C", 25 September 2017, see: http://data.parliament.uk/writtenevidence/committeeevidence.svc/evidencedocument/public-accounts-committee/hinkley-point-c/written/70983.pdf, accessed 17 June 2018.

89. Stephen Lovegrove, in Public Accounts Committee, "Oral Evidence: Hinkley Point C, HC 393" (London, 2017), https://www.parliament.uk/business/committees/committees-a-z/commons-select/public-accounts-committee/inquiries/parliament-2017/hinkley-point-c-17-19/publications/.

90. https://www.theguardian.com/uk-news/2017/oct/12/electricity-consumers-to-fund-nuclear-weapons-through-hinkley-point-c, accessed 12 October 2017.

91. E.g: Peter Wynn-Kirby, "Britain's nuclear coverup" *New York Times Online,* 10 October 2016*,* see https://www.nytimes.com/2016/10/11/opinion/britains-nuclear-cover-up.html?mcubz=3, accessed 18 June 2018. Also; Ralph Sotscheck, "Britisches AKW Hinkley Point C: Hidden Money für Atom-U-Boote" *Die Tageszeitung Online,* 23 November 2016; see http://www.taz.de/!5356383/, accessed 18 June 2018.

92. Offshore wind power was being contracted for in the U.K. in 2017 at 55 £/MWh, against the backdrop of a long-run steady decline in costs. Power from Hinkley Point C, by comparison, is awarded Government-guaranteed contracts over 35 years from planned completion of the plant in the mid 2020s at a value set (in comparable 2017 prices) at 102.5 £/MWh (against a worldwide backdrop of steady increase in nuclear costs). Even if it is assumed (in a way that is highly unfavourable to wind power) that this currently-accelerating renewable cost advantage remains unchanged from 2017 not only until completion of Hinkley Point C, but also (even more unfavourably to wind) throughout the entire projected 35-year duration of the contracts, then the (significantly understated) scale of the opportunity costs over this period would amount to some £30 billion. And this is exactly the figure given by the NAO for the "top up payments" associated with the unfavourable contract for Hinkley Point C alone (NAO. "Hinkley C", *National Audit Office,* 23 June 2017). Similar contracts under development for other UK civil nuclear stations would significantly add to this figure. And, that offshore wind is also considerably more expensive than onshore wind, with costs of solar power falling even more steeply, further underscores the highly conservative nature of this indicative minimum figure for the total flows of revenue associated with this strategy.

93. The US *New York Times* and German *Tageszeitung*, for instance, each prominently covered this analysis (respectively), in October and November 2016. But it was not until October 2017 that any UK newspaper picked up the story. Over the course of a two year period prior to this, the present authors contacted 12 leading specialist nuclear journalists in the mainstream UK print and broadcast media. Of these, 9 expressed active interest. Yet (once as late as one day before an invited live interview on a flagship national radio news programme), every one of these 9 journalists had the story turned down by their editorial desk. There were three broad stated (oddly contradictory) reasons for this, para-phraseable as: 'this is too obvious'; 'it is a conspiracy theory'; 'it is not intelligible'. It was not until a senior civil servant confirmed the basic substance of the links in October 2017 under questioning by a Parliamentary Select Committee based on grounds of the present authors' evidence, that two *Guardian* articles were published on the issue in October and December 2017. The writer of these articles (Holly Watt) has no specialist energy, nuclear or defence background, but a general investigative remit. And even here, the *Guardian* editorial desk still remained uninterested until one of the present authors contacted them directly to point out the risk that inertia by this newspaper might itself otherwise become part of the story. Despite continued accumulation of further evidence and the lack of any government refutation, it is still the case that no other mainstream UK news outlet has since given any coverage to the issue whatsoever. This seems odd, since it does not require acceptance of every feature of the present analysis, to appreciate that substantive queries are raised that might reasonably be seen to warrant at least some kind of attention. When compared with intense media coverage of multiple relatively routine and small-scale features of energy policy, this persistent neglect is itself notable; suggesting (at minimum) tight limits on mainstream political, policy and technical imaginations and a certain reluctance to raise difficult questions.

94. Respected energy analysts Jessica Jewell and Aleh Cherp of the Polet Network based at the Central European University, are among those expressing this reaction, for instance in a blog by Jessica Jewell, Proving the deep state requires deeper reasoning, Polet Network Blogspot, 30th September 2015 (available here: http://polet.network/blog/2015/9/24/shallow-reasoning-on-the-deep-state). A first response from the present authors is here: A. Stirling, P. Johnstone, On the Deep State Hypothesis, Polet Network Blogspot, 6th January 2016 (available here: http://polet.network/blog//deep-state-uk-response). Also Jessica Lovering of the Breakthrough Institute also referred to this research as a "conspiracy theory". See Lovering, J. (2016) Britain's civil nuclear programme is not a stealth military programme. 18th October 2016. (Available here: https://thebreakthrough.org/index.php/voices/britains-civilian-nuclear-program-is-not-a-stealth-military-program)

95. This is all the more so, because of the strangely neglected obviousness of the point, that the most effective way to address the global threat from nuclear weapons has always been to also end the use of nuclear power – as (for instance) explored in 1996 by the leading US nuclear weapons designer Theodore B. Taylor; Theodore B. Taylor, Nuclear Power and Nuclear Weapons, Nuclear Age Peace Foundation, July 1996. Available here: https://www.wagingpeace.org/nuclear-power-and-nuclear-weapons/. These issues are also discussed in Z. Mian, Beyond the Security Debate: The Moral and Legal Dimensions of Abolition in Perkovich, G. & Acton, J. M., eds. Abolishing Nuclear Weapons: a debate. (Carnegie Endowment for International Peace).