Scientists for Global Responsibility
Scientists · Architects · Engineers · Technologists

SGR Newsletter

Winter 2016
Issue 44 • £3.50

UK climate policy unravelling

© Ian Taylor

Caton Moor wind farm near Lancaster. Recent changes to UK climate policy undermine new wind and solar projects in favour of fracking and nuclear projects.

The government claims that the UK is taking a leading role in tackling climate change – but support mechanisms for renewable energy and energy conservation are rapidly being cut. Stuart Parkinson, SGR, examines what is going on.*

The Conservative government has recently been very upbeat in its assessment of UK climate policy. In October, Secretaries of State, Amber Rudd and Liz Truss, wrote: "We should be proud of what we have achieved so far to tackle climate change. Our track record is strong. Provisional figures for 2014 show that emissions fell by 8.4% between 2013 and 2014 while the UK's economy grew by 3%. Our renewable electricity capacity almost trebled between 2010 and 2014."[1]

Yet the government has spent the period since the General Election in May instigating large cuts to subsidies for renewable energy and energy conservation programmes. It is claimed that these cuts will not jeopardise Britain's ability to reduce carbon emissions on the scale required to adequately tackle climate change. It is also claimed that these cuts are necessary "to keep bills as low as possible for hardworking families".[2]

So are they right? To answer this, we need to dig into the evidence.

Some successes

The most recent detailed assessment of the progress made by the UK on reducing carbon emissions was provided in a progress report[3] by the government's advisory body, the Committee on Climate Change (CCC), published last summer.

The headline figure was that the UK's carbon emissions in 2014 were 36% below 1990 levels – on track to exceed near-term targets set under the UK Climate Change Act. Electricity generated from renewable energy sources had reached 20% of the UK total – four times the level in 2007 and ahead of nuclear for the first time. Indeed, the figures[4] for the first nine months of 2015 show that renewables generation has risen even higher, now supplying more electricity than either coal or nuclear. The CCC's report also showed that installation to date of the most common home energy efficiency measures – such as loft insulation and energy-efficient boilers – was also ahead of targets, industrial carbon emissions had markedly fallen and sales of electric vehicles had also exceeded targets. These achievements reflected the success of a number of policies brought in by governments over many years and from across the political spectrum.

Since the CCC's report, the government has also announced[5] its intention to phase out coal (without carbon capture technology) in the electricity sector by 2025 – a proposal which has earned it international praise.

On the face of it, these are laudable achievements – and this was reflected in the UK being rated as one

continued on page 19

* NB. This article focuses on UK policies aimed at reducing carbon emissions rather than on adapting to the impacts of climate change.

Contents

A few words from the Director

In December, the UK began a new campaign of air strikes in Syria – making it the 14th nation (apart from Syria itself) to bomb in the country since September 2014.[1] Quite what the RAF can achieve in Syria with its military technology that other air forces haven't remains unclear. And Syria is, of course, the fourth Islamic nation that the UK has bombed this century as part of the ill-fated 'War on Terror'.[2] It is difficult to think about this situation without recalling the saying – often attributed to Einstein – that "insanity is doing the same thing over and over again and expecting different results". I should emphasise that I am in no way trying to downplay the considerable difficulty of bringing peace to Syria, but it is hard to fathom why the British politicians who voted in favour of air-strikes think that more bombs will help – especially at this stage. Britain has a great deal of skills and expertise that can alleviate the suffering and help to bring an end to this conflict – not least in peace studies and engineering. Such skills can help with negotiating ceasefires, providing humanitarian aid, supporting refugees, closing down funding pathways for so-called Islamic State, and restricting the influx of foreign combatants and weapons. The UK is active in many of these areas, but many more resources are needed.

A touch of insanity can also be seen elsewhere in the UK government's application of science and technology. Most obviously, this is the planned replacement of the Trident nuclear-armed submarines, a parliamentary vote on which is due soon. This has long been a key concern of SGR, and we have stepped up our activities in this area – see p.3. Indeed, with deeply flawed arguments being repeated in support of Trident replacement, this newsletter includes an article which challenges many of them on p.5. We urge our members to support UK nuclear disarmament campaigns, especially at this important time.[3]

Another area where insanity has touched government policy recently is on climate change – as the article on p.1 shows. In the light of the landmark Paris Agreement – see p.11 – it is important that we continue our activities (see p.4) in support of a major policy change, not least given the increase in spending on a wide range of military technologies (see p.7) and cuts to support for renewable energy technologies that we have witnessed in recent months. Indeed, as we approach the 30th anniversary of the Chernobyl accident and the fifth anniversary of the Fukushima accident, on p10 we feature an important new analysis which shows that nuclear power stations are not as safe as the industry claims.

Another anniversary that highlights a descent into madness is the centenary of the Battle of the Somme in 1916. The article on p.14 provides a timely examination of how engineers and scientists were central to the carnage of World War I, and what lessons we should take for today.

Lessons are also a growing dimension of SGR's work as our Science4Society Week expands – providing an alternative to arms and fossil fuel industry-funded education activities that are prominent in schools. We preview this year's S4S Week on p.12. Please encourage any science teachers you know to get involved!

Since the General Election last May we have seen a government intent on pursuing militaristic policies and cutting back on efforts to use science and technology in a transition to a just and sustainable society. Working with a range of like-minded organisations, SGR will continue to challenge them.

Stuart Parkinson

Notes

1. The other 13 nations are the USA, Australia, Bahrain, Canada, France, Jordan, Morocco, The Netherlands, Qatar, Russia, Saudi Arabia, Turkey, and the UAE – although there is some ambiguity over the exact role of some nations' air forces. For more details, see e.g.: Wikipedia (2016). en.wikipedia.org/wiki/American-led_intervention_in_Syria
2. This label is no longer used by the US-led coalition.
3. For example, CND: cnduk.org

The new National Co-ordinating Committee

The election for SGR's National Co-ordinating Committee for the coming year was held during the Annual General Meeting on 31 October 2015 (see report on p.21). The following were elected:

Chair: Dr Philip Webber
Vice-chair: Dr Jan Maskell CPsychol
Treasurer: Alasdair Beal CEng
Secretary: Dr Charalampos (Harry) Tsoumpas

Committee members:
Martin Bassant MPhil; Gwen Harrison MSc; Dr David Hookes; Dr Paul Marchant CStat

Most of the NCC and staff (from left to right): Paul Marchant, Jan Maskell, David Hookes, Vanessa Moss, Alasdair Beal, Philip Webber, Gwen Harrison, Stuart Parkinson

New SGR report on nuclear weapons

On 70th anniversary of the dropping of the Hiroshima atomic bomb (6 August 2015), SGR launched a new report, *UK nuclear weapons: a catastrophe in the making?* written by Philip Webber and Stuart Parkinson.

The report updates and summarises the latest scientific and technical information about the risks posed by the continued deployment of the UK's nuclear weapons. It highlights the following.

- The explosive power of the nuclear weapons carried on just one Trident submarine is equivalent to around 320 Hiroshima bombs and is capable of inflicting more than 10 million civilian casualties.
- The most up-to-date scientific models predict that this firepower would cause devastating climatic disruption threatening global food supplies and leading to mass starvation.
- UK nuclear weapons are on patrol around the clock, and the possibility of unintended use poses an unacceptable risk. While the chances may be low, the consequences would be catastrophic.

Over 3,500 copies of the report were downloaded in the first six months after publication, and printed copies have been sent or given to senior MPs and peace campaigners and researchers to support the case against the replacement of Trident, on which a parliamentary vote is expected in spring this year.

Other related activities

Philip Webber also had an opinion piece summarising the case against Trident replacement published in *New Scientist*, with another article appearing in *Peace News*. Related articles on the SGR website have also received a great deal of interest. He has also spoken at two anti-nuclear events – an international campaigners' event in London and a public meeting in Exeter – as well as taking part in several other campaign events over recent months. His lecture at the SGR conference on nuclear weapons and climate change is summarised on p.22 with an article summarising the flaws in UK nuclear deterrence appearing on p.5. Other media coverage has included being quoted in *The Guardian* as the debate on Trident has received a great deal more coverage in the wake of Jeremy Corbyn's election as leader of the Labour Party.

Challenging military science and technology

SGR continues to challenge military science and technology, especially in the UK.

The main focus over the past few months has been to promote alternatives to militarism as the government carried out its Strategic Defence and Security Review (SDSR) (see p.7 for more details of the review). We submitted a response to the public consultation on the SDSR, arguing that the UK should shift its security strategy from heavy reliance on offensive weapons systems, such as nuclear arms and long-range conventional weapons, to a focus on tackling the roots of conflict. We also argued, in a submission to the House of Commons Committee on Science and Technology, that the high level of public spending on military R&D should be reduced in favour of civilian R&D that helps prevent conflict. We worked with other peace organisations to increase media coverage of our concerns.

We also supported campaigners against military influence at universities. David Hookes contributed to a report on military R&D at Liverpool University. He also spoke at a public meeting on the issue. We also provided information to students at the University of West England and Southampton University.

Stuart Parkinson ran two workshops on military industry and the alternatives at the National Justice and Peace conference in Derbyshire in the summer.

Finally, we supported various campaign activities on drone warfare, including co-signing an international open letter by computer scientists arguing for a ban on offensive autonomous weapons.

Scientists for Global Responsibility presents

Science4Society Week 2016

14th to 20th March

Science education activities to inspire young people

(which are not funded by arms or fossil fuel corporations!)

For more information, see p.12

In brief

Stuart Parkinson gave a talk entitled *From corporate science to science for society* at a TEDx event in Lancaster. The talk can be viewed on the web via: www.sgr.org.uk/resources/corporate-science-science-society

Sponsors news

Sadly, Derek Sugden, leading structural engineer and acoustician, and sponsor of SGR, has died aged 91. An obituary will appear in the next issue.

Staff update

Office Manager, Vanessa Moss has moved from being maternity cover for this post to holding a permanent contract, as Georgina Sommerville resigned to spend more time with her young family. We wish Georgina all the best for the future.

Climate change and energy activities

SGR has been very active making the case for concerted action to tackle climate change.

With the Paris climate negotiations, of course, being the most important policy event of 2015, we took part in numerous activities focused on this. Our annual conference, held in London a month before the formal negotiations opened, dealt with the theme, *Messages for the Paris conference: the forgotten dimensions of climate change* (see p.21). Stuart Parkinson and Jan Maskell attended several of the Paris events, with Stuart speaking at a packed workshop on 'War, military and climate' at the People's Climate Summit (see photo bottom left). Stuart also wrote a widely publicised blog on climate and insecurity in advance of the negotiations. SGR also worked with campaign organisations through The Climate Coalition to push for a strong agreement in Paris. Numerous SGR members also took part in climate-related demonstrations in support of positive outcome (see for example, photos right and bottom right), as well as voicing their concerns through social media.

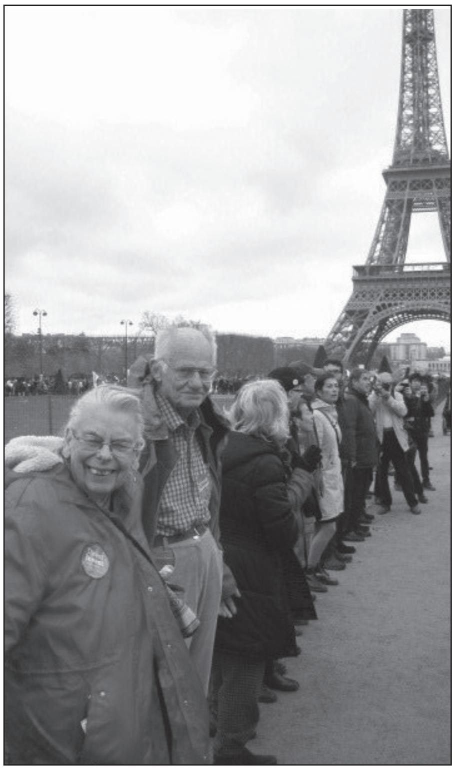
Another major focus of SGR's efforts in recent months has been to argue against the Conservative government's roll-back of UK climate policies (see article on p.1). We have responded to some of the consultations on proposed cuts to subsidies for renewable energy and signed joint letters to leading newspapers arguing for a change in direction from a future based on nuclear power and shale gas to one that prioritises energy conservation and renewable energy. On SGR's blog, several climate scientists and energy policy analysts have also made similar arguments. In a widely-circulated article on *The Ecologist* website, Stuart Parkinson pointed out that government policy now seems to be to cut science and technology jobs in the renewables sector and increase them in the nuclear weapons industry – obviously, the exact reverse of what we need. Gwen Harrison had a letter published in *The Guardian* criticising government subsidies for fossil fuels.

Stuart has spoken at three other events in recent months. The first was a seminar on fracking for local councillors in Wakefield, West Yorkshire, and the others were a 'zero carbon' conference and a public meeting discussing the outcome of the Paris negotiations – both held in Lancaster.

We have also continued to provide information and support to anti-fracking campaigners, especially in Lancashire and Lincolnshire, as well as to student-led fossil fuel divestment campaigns at UK universities.

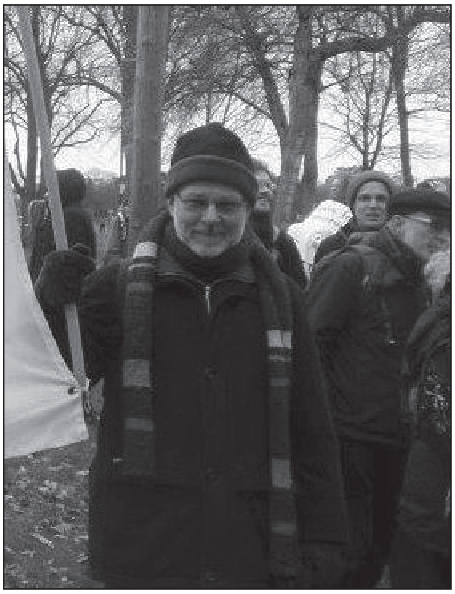
Finally, we lent our support to a US-led campaign which urges science museums to cut their funding links with fossil fuel industry sources. The campaign has already had a number of successes, including the news that David Koch, US oil billionaire and funder of ideological climate sceptic groups, has decided to step down from the board of the American Museum of Natural History in New York.

SGR members join climate demos in Edinburgh...



...and Paris...

Stuart Parkinson speaks on the UK military-industrial complex and climate change at the People's Climate Summit in Paris in December



...and Leicester

Trident, deterrence and UK security

Philip Webber, SGR, summarises the flaws in the theory and practice of nuclear deterrence for the UK.

Despite recently uncovered historical evidence of nuclear ‘near misses’ and growing scientific evidence of the devastating global consequences of the use of only a few nuclear weapons, there is still a widespread belief in the value of these weapons among senior policy-makers in the nuclear-armed nations. In the UK, this manifests itself in a cross-party parliamentary majority in favour of replacing the Trident system. This is largely because of a widespread belief in nuclear deterrence. Here I highlight the numerous flaws in the arguments made in support of deterrence, in the hope that some of them may help campaigners more effectively challenge their political representatives as the parliamentary vote on the replacement of Trident approaches in early 2016.

Some key arguments are repeatedly put forward by the Government – most recently as part of the Strategic Defence and Security Review (SDSR)[1] in November 2015 – as well as by other supporters of nuclear weapons:

- UK weapons are at a “minimum, credible” level;[2]
- The nuclear deterrence effect works “every day”;[3]
- They have kept the UK out of conflicts for the last six decades;[3,4]

I will take these points in turn and also address other deficiencies in nuclear weapons policy in the SDSR.

Are UK weapons at a “minimum, credible” level?

We have shown in SGR briefings and other publications, based on the latest scientific modelling, that the launch of the missiles from a single British Trident submarine would directly cause 10 million civilian casualties and also lead to a decade of climatic cooling and drought severely affecting global food supplies.[5] Use of Trident would be completely disproportionate: both genocidal and suicidal. This level of destructive capability is very far above any reasonable criterion of “minimum”.

The Government asserts that Trident is “minimum” on the basis that: “we possess only approximately 1% of the total global stockpile of nuclear weapons”.[6] The correct implication to draw from this is that global stockpiles represent the ability to destroy civilisation many times over and that international efforts to dramatically reduce warhead numbers need to be stepped up urgently.

There is also an implication for the credibility of nuclear deterrence. As nuclear use would have such terrible consequences for the nation that launches nuclear weapons – as well as for the target nation – any threat of nuclear use becomes much less credible and arguably not credible at all.

As it is, the Government and the Ministry of Defence refuse to acknowledge or engage with the latest evidence on the destructiveness of nuclear weapons.[7] One can presume this is because admitting these facts would undermine the repeated assertion of nuclear deterrence that is held up as so vital for the UK’s security.

Does nuclear deterrence work every day and has it done so for six decades?

It may be the case that nuclear weapons have had some deterrent effect, but it is deeply flawed to argue that it is reliable. The absence of nuclear war doesn’t give clear proof of the effectiveness of nuclear deterrence in the same way that habitual smokers cannot claim that smoking is safe because they are still alive and well. One thing we do know is that we have not had a nuclear war despite nuclear weapons. The evidence from six decades without nuclear war is that we have come perilously close to nuclear destruction on many occasions. This has arisen due to a range of causes: false alarms; military exercises that became too realistic; faulty equipment; human error; and political brinksmanship.[8] There are numerous examples from history showing when nuclear deterrence has failed, not least the Argentinean invasion of the Falkland Islands in 1982.[9]

The simplest explanation for the lack of an attack by the Soviet Union on NATO countries is that there was no intention to do so and that the large nuclear deployments on both sides are symptoms of a political failure to demilitarise. Large non-nuclear military forces were more credible as a deterrent to conflict as is the memory of massive Russian casualties during the two previous world wars. Sometimes, diplomacy worked.

To the historical near misses, we now have to add an ongoing and growing risk of cyber-attack or hacking. A former commander of US strategic nuclear forces urges that the 1,800 Russian and US weapons currently deployed on high alert and kept ready-to-fire should immediately be de-alerted and physical measures be taken to lengthen the time needed to launch a weapon. This is to avoid the risk of hacking leading to an unintended launch due to the very short decision times of as little as 10 minutes if incoming attack is suspected to be in progress.[10] Hacking is also a risk for UK nuclear forces. The UK Government asserts that there is no hacking risk on the basis that systems are ‘air-gapped’, i.e. not connected to the internet. However, sophisticated methods can bypass the internet via smart-phones, memory sticks or apparently innocent industrial components, as shown by the case of the Stuxnet virus infection of Iranian nuclear facilities.[11] Nuclear deterrence whether effective or not cannot possibly deter miscalculations or accidents.

Ignoring the threats created by nuclear weapons

The latest SDSR does not consider or even mention a whole set of threats that arise from the continued stockpiling and deployment of nuclear weapons around the world, including in the UK. These include:

- an intercontinental nuclear conflict – involving the arsenals of the US, Russia or China;
- a regional nuclear conflict – for example India and Pakistan;
- the global, disproportionate impact of the sole use of the UK Trident system;
- the possibility of any of the above scenarios arising due to miscalculation, accident or hacking;
- the increased dangers of weapons deployed on ‘high alert’ status.

These are major omissions.

The future role of the UK’s nuclear weapons

The SDSR lists a number of future threats that UK nuclear weapons are intended to deter.[12]

These include the risk of nuclear missile attack by state or non-state ‘actors’. The UK’s position on the Atlantic coast is far from any possible new state-based nuclear threat. The only realistic locations for such threats are in the Middle or Far East. The historical lesson is that the intention of any such state is to try to create its own regional nuclear ‘deterrent’ – and the cases of Iran and North Korea are relevant here. The recent response to Iran is showing how the international community can use both negotiations and sanctions to prevent the possibility of a new nuclear weapons capability. The case of North Korea shows that the deployment of US nuclear-armed aircraft in the region has arguably led to a more aggressive response from that country rather than the reverse. One thing that is definitely clear is that UK nuclear weapons have been completely irrelevant to both situations.

Turning to non-state actors, there is a very real possibility that terrorists could use highly radioactive nuclear materials with explosives to spread radiation. The only solution is effective policing and controls of nuclear materials including medical sources. UK nuclear weapons could not possibly be of any use in deterring this threat. In fact, some terrorist groups might see it as a success if they could prompt a nuclear response.

The SDSR cites the value of UK Trident in countering a theoretical future threat from Russia (or possibly China). This argument is simply not credible as the overwhelmingly dominant factor in such Russian calculations would be the hundred times larger US nuclear arsenal. British nuclear weapons are irrelevant.

And all of this discussion assumes intent. Russia has major trading relations with NATO countries. Russia also suffered terribly during World War II – with 8.5 million soldiers dead and perhaps double this number of civilians killed, by far the largest casualties of any nation involved. The idea that it would risk launching a major assault on NATO – whether nuclear-armed or not – is hardly credible. Political and economic action and – in extreme circumstances – non-nuclear military forces are more than enough to deal with such a risk. NATO currently dramatically outspends Russia on its military forces by a factor of ten,[13] which rather begs the question of who is threatening whom?

The recent conflict in Ukraine (including Crimea) arguably reflects old ideas about 'spheres of influence'. While Russian actions may be unacceptable, such a conflict may also be partly a result of a new nationalism among Russian-speaking minority groups in some Eastern European and former Soviet countries, and a reaction to NATO's expansion eastwards to the borders of Russia.

Nuclear hypocrisy and inconsistency

The arguments in favour of nuclear deterrence, used by the UK and other nuclear-armed states, can be used by any country. If nuclear deterrence 'works' then, to follow the logic of this proliferation argument, every state should be armed with nuclear weapons. Such beliefs have been the driver of nuclear arms races such as during the Cold War, or the nuclear stand-off between India and Pakistan and are clearly understood by North Korea.

This double standard, that the existing nuclear states *require* nuclear weapons for their security but that other non-nuclear states *cannot* have nuclear weapons to avoid greater insecurity, has been the source of a growing reaction at the UN, particularly as progress on disarmament has almost stopped and huge arsenals remain. It is the primary driver for the start of a new multilateral legal process towards a nuclear ban treaty supported by 135 non-nuclear states.[14]

Conclusion

The US and Russia continue to deploy very large numbers of nuclear weapons, but the UK's arsenal also represents a major threat. While nuclear deterrence may work on *occasion*, it also *creates* an enormous risk – that of the destruction of civilisation – through the continued deployment of nuclear weapons. Russian and US weapons kept on high alert markedly heighten this risk. Launch command and control technology further add to the risk through its vulnerability to miscalculation, accident and cyber-attack. The UK's nuclear arsenal is irrelevant in deterrence terms in relation to these very large arsenals, but its role in disarmament *could* be very significant. The UK could choose a different political path similar to that chosen by South Africa, Brazil, Japan and a large number of nations which, while possessing the technological ability to make nuclear weapons, see the benefits of not having such arms. This path would help to improve international security.

The UK could take a leading role in reducing the risk of nuclear war by immediately:

- taking Trident nuclear submarines off patrol;
- placing warheads in storage;
- cancelling the replacement of the Trident submarines; and
- actively supporting an active UN/multilateral process for a global nuclear ban.

There would obviously need to be further steps towards complete disarmament as a multilateral process proceeded.

This in my view would be the responsible and enlightened course of action for the UK in its current situation. We only have this one planet and the use of nuclear weapons would have disastrous world-wide consequences. No nation can create security for itself by threatening nuclear devastation 'elsewhere'.

Dr Philip Webber is Chair of SGR and author of numerous books and reports on nuclear weapons.

Thanks to Stuart Parkinson for very helpful editorial inputs.

Notes and references

1. HM Government (2015). National Security Strategy and Strategic Defence and Security Review 2015. www.gov.uk/government/publications/national-security-strategy-and-strategic-defence-and-security-review-2015
2. The UK nuclear weapons system is a "minimum, credible, independent nuclear deterrent". Section 4.65 of: HM Government (2015) – as note 1.
3. "Our nuclear deterrent works. It deters aggression every single day. There have been many conflicts in the last six decades, and not one of them has involved a direct conflict between nuclear states. Not one country under the protection of an extended nuclear umbrella has been invaded." Hansard (2015). M Fallon MP, UK Secretary of State for Defence, HC Deb, 24 November, c1210.
4. "NATO countries sign that alliance for a very good reason. It is because nuclear weapons work. Since 1949, no two nuclear states have fought each other or gone to war in any way." Hansard (2015). T Tugendhat MP, HC Deb, 24 November, c1226.
5. SGR (2015). www.sgr.org.uk/resources/nuclear-weapons-and-climate-catastrophe
6. Section 4.78 of: HM Government (2015) – as note 1.
7. Hansard (2015). Exchange between J Corbyn MP and The Minister for the Armed Forces, Mr Mark Francois (and others). 12 January, c584. www.publications.parliament.uk/pa/cm201415/cmhansrd/cm150112/debtext/150112-0001.htm#15011222000023
8. Schlosser E (2013). Command and Control. Penguin. Lewis P et al (2014). Too Close for Comfort: Cases of new nuclear use and options for policy. Chatham House. www.chathamhouse.org/publications/papers/view/199200
9. Beach H (2011). What price nuclear blackmail? Abolition 2000. abolition2000uk.org/Blackaby9.pdf
10. General Cartwright, quoted in an interview by Associated Press. Cartwright headed Strategic Command from 2004-07 and was vice chairman of the Joint Chiefs of Staff, retiring in 2011. The Diplomat (2015). thediplomat.com/2015/05/could-cyber-attacks-lead-to-nuclear-war/
11. Christian Science Monitor (2014). www.csmonitor.com/World/Security-Watch/2014/0225/Exclusive-New-thesis-on-how-Stuxnet-infiltrated-Iran-nuclear-facility
12. Section 4.16 of: HM Government (2015) – as note 1.
13. SIPRI (2015). Military Expenditure Database. www.sipri.org/research/armaments/milex/milex_database/milex_database
14. Webber P (2015). www.sgr.org.uk/resources/135-reasons-not-replace-trident

A new phase for 'offensive insecurity'?

Stuart Parkinson, SGR, gives an overview of the UK's new military and security strategies, and highlights the increasing focus on militarism.

The government published its new combined National Security Strategy (NSS) and Strategic Defence and Security Review (SDSR) in November 2015.[1] When SGR critically examined its 2010 predecessor – especially the role of science and technology within it – we pointed out that its emphasis on 'force projection' and limited attention to tackling the roots of conflict pointed to a strategy of 'offensive insecurity'.[2] So what has changed in the 2015 document?

A lot more military tech

The most prominent aspect of the new strategy is the marked increase in military equipment spending planned for the next 10 years. There is to be a rise of £12 billion to the enormous total of £178bn – at a time when many areas of government spending, such as welfare and environmental protection, are being drastically cut. The spending will enable Britain to:

- deploy its two new huge Queen Elizabeth-class aircraft carriers in the early 2020s with larger numbers of F-35 Lightning fighter-bombers;
- continue with the plans to build four new submarines to carry its Trident nuclear weapons (subject to a final government decision due in early 2016);
- deploy a new fleet of nine maritime patrol aircraft;
- create two new Army strike brigades, capable of being deployed overseas at short notice;
- expand the number of armed drones to 20;
- extend the life of the Typhoon fighter jets; and
- continue with plans to develop, manufacture and deploy a range of new warships, conventionally-armed submarines, weapons systems and other military technology.

While there are some technologies which could be argued to have a mainly defensive role – such as the maritime patrol aircraft – the main focus is clearly on an increase in offensive capability or, as the Ministry of Defence prefers to call it, 'expeditionary capability'. The justification for this marked increase in militarised force posture is the 'resurgence' of Russia, the rise of Daesh/ Islamic State in Iraq and Syria, growing instability elsewhere in the Middle East and North Africa and the related threat of international terrorism. These threats, the government argues, requires Britain to take a more aggressive role in international affairs. Such a position is emphasised by the parliamentary vote in early December to begin air strikes in Syria against Daesh forces, in addition to those already being carried out in Iraq.

The industries that will manufacture all this new equipment will be given enhanced support from government to access new funding (especially for exporting), build partnerships with corporations not yet involved in military work, train new engineers and scientists (especially through apprenticeships), and build stronger links with universities.

The increased concerns about cyber-security threats also mean that government funding in this area will continue its rapid rise. One consequence of this that is already clear is that more military corporations are becoming involved in civilian security work.

Overseas aid, climate change and security

Despite the emphasis on the role of armed approaches, there are some notable non-military aspects to the NSS/SDSR.

One example is that the UK's spending on overseas aid is to be maintained at the international target of 0.7% of Gross National Income, and at least half the funds will be directed to 'fragile nations' in which conflict may arise. Conflict prevention measures will be financed by a Conflict, Stability and Security Fund with a budget of nearly £6bn over five years.

The NSS/SDSR also states that "Climate change is one of the biggest long-term challenges for the future of our planet." As such, the five-year budget for the UK's International Climate Fund – aimed at helping developing nations with both adapting to climate change and investing in greener technologies – is to be increased to £5.8bn.

Strategic failings

The growing fears about terrorism and Russia have led to a traditional response among UK policy-makers that emphasises the 'hard power' option of developing and deploying lots of military technology. Yet this response is being constrained by a budget that is at historically low levels, just above 2% GDP. Spending pressures have thus helped to encourage the government to also expand some conflict prevention efforts, especially via overseas aid and climate-related budgets. Nevertheless, the failings of the NSS/SDSR are serious.

Firstly, there is a continued lack of recognition that deploying more UK military forces in Middle East can fuel the cycle of violence. There is a disturbing lack of acceptance about the failures of previous Western 'military interventions' in Iraq, Afghanistan, and Libya. While British humanitarian aid to the region is very welcome, the attention given to other security measures – such as cutting off funding pathways to Daesh, strengthening border controls to prevent foreign fighters entering war zones and diplomatic efforts to achieve ceasefires – are far too limited.

Secondly, there is a refusal to recognise that UK arms exports to authoritarian regimes are fuelling armed conflict, undermining human rights and leading to civilian deaths. For example, it is likely that UK-made weapons have been used by the Saudi Arabian-led coalition in its increasingly indiscriminate military campaign in Yemen.[3] Against this background, the stated aim of the NSS/SDSR to "Maximise prosperity opportunities from our defence... activities" looks irresponsible in the extreme.

Thirdly, there is a failure to appreciate the urgency of environmental threats. The lack of preparedness in dealing with the December 2015 floods has once again focused public attention on the chronic underfunding of flood defence/ prevention measures. Meanwhile, the NSS/SDSR demonstrates a lack of understanding of the full scale of the climate change threat – and the importance of a UK lead in cutting carbon emissions – an attitude which is sadly prevalent across government (see p.1).

Finally, there is no acknowledgement of the threat to international security created by the continued deployment of nuclear weapons by the UK – or indeed the USA and France (see p.5).

In summary, the welcome increase in funding to help tackle the roots of conflict is being thoroughly swamped by the much larger increase in spending on militaristic approaches. Ethically-concerned engineers and scientists will have to work even harder to avoid being co-opted into this agenda.

Dr Stuart Parkinson is Executive Director of SGR and lead author of the SGR report, *Offensive Insecurity*.

References

1. HM Government (2015). National Security Strategy and Strategic Defence and Security Review. www.gov.uk/government/publications/national-security-strategy-and-strategic-defence-and-security-review-2015
2. SGR (2013). Offensive Insecurity. www.sgr.org.uk/publications/offensive-insecurity
3. The Conversation (2016). theconversation.com/parliament-urgently-needs-to-keep-tabs-on-britains-arms-exports-52865

Ocean acidification: a threat to life

Wiebina Heesterman examines the other threat from carbon dioxide emissions: that of ocean acidification.

Healthy oceans are essential to our existence – and not only humans suffer from the deteriorating state of the world's oceans; biodiversity is also critically at risk. Seafood, both caught in the wild and farmed, forms the main source of protein of some three billion people,[1] while it is a staple for nearly one billion, mainly in the developing world.[2] Seas and oceans play an important role in sequestering carbon dioxide: over 30% is taken up by our oceans, which are still continuing to absorb about a million tonnes per hour.[3] As expressed on the UN 'Oceans Day 2015' website:

"Oceans and climate are intertwined, with oceans driving climate and climate change affecting ocean health and coastal and island peoples. Oceans cycle over 93% of carbon dioxide in the atmosphere, produce 50% of the oxygen we breathe, store 50% of all naturally sequestered carbon, and absorb 90% of the heat added to the global system in the past 200 years."[4]

The menace of climate change due to increasing CO_2 emissions from human activities is, of course, well known. However, the constant exchange of this gas between the atmosphere and oceans leads to a second global problem: that of ocean acidification. In this article, I will examine this threat by focusing on three broad habitats where the impacts are very different: the open oceans and coral reef seas; ice-covered polar seas; and volcanic deep-sea vents.

The open ocean and coral reef seas

Some of the carbon that goes into the top ocean layers is taken up by phytoplankton, the tiniest algae that drift close to the surface. There sufficient sunlight penetrates to allow plants to make sugars from CO_2 by photosynthesis – and also provide the world with some more breathable oxygen. These tiny plantlets get consumed by all kinds of sea creatures, above all the multi-trillions of roaming zooplankton who migrate up from the seafloor to feed at night, returning to their bottom dwelling place by day. At their death, the tiny bodies gradually sink to the seafloor with the CO_2 safely deposited in the form of organic carbon which can be recycled into nutrients by bacteria, to be consumed again by other creatures. But the bulk of this massive ocean life – estimated to amount to some 90% of all marine biomass – is eaten during their migration by larger marine life such as sea butterflies, krill, shrimps, jellyfish and blue whales. The smaller of these are, in turn, eaten by other sea creatures, such as fish, and at the top of the chain there are sharks, sea otters, seals, sea birds, and not to forget humans.

Unfortunately, much of the CO_2 absorbed by the oceans does not go down with the zooplankton; instead it dissolves and combines with seawater. This may rise back up into the much warmer atmosphere in places of major upwelling, as for instance at the Chilean coast, where the nutrient-rich Antarctic water[5] from the Humboldt Current emerges. The remaining unsequestered CO_2 has the unfortunate effect of changing ocean chemistry for the worse. Whereas ocean water is slightly more alkaline than tap-water, the dissolved CO_2 combines with seawater to form carbonic acid – no more than a fairly weak acid, but still sufficiently so to affect shell-forming organisms. These include life-forms at the bottom of the food chain as well as many higher up such as sea butterflies, shellfish and corals. Coral reefs suffer a 'double whammy' from climate change: warmer water leads to coral bleaching,[6] in effect robbing the coralline seaweeds that serve as glue to keep corals together of their brilliant colours, while the loss of alkalinity attacks the fabric of the reefs. As these support a scarcely imaginable variety of life – their demise would be a catastrophe for organisms dependent on marine food webs.

Ice-covered polar seas

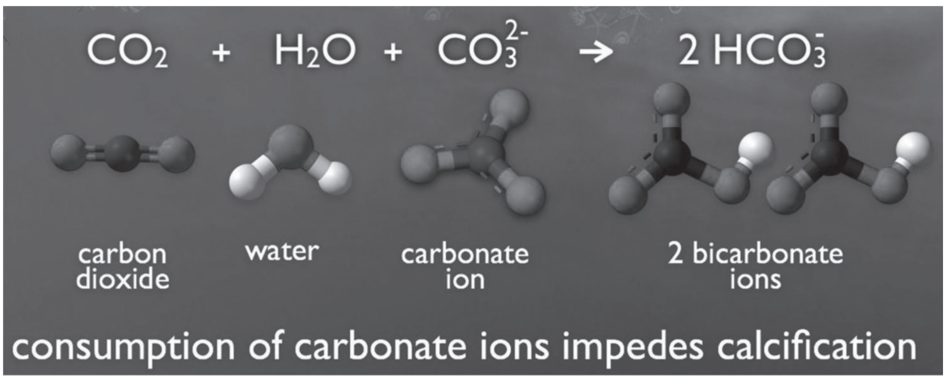
In polar habitats, such as under the shelf ice of the Antarctic Peninsula, diatoms (a type of phytoplankton) grow suspended from the drifting ice,[7] which still lets a small quantity of sunlight through. Otherwise the food chain is roughly similar to the one described above, but with very different marine life. Unfortunately, weakening of the alkaline character of seawater is strongest at high latitudes,[8] while warming there too is climbing much faster than elsewhere. In consequence, Arctic sea life is likely also to be attacked by predators migrating poleward, such as king crabs, already observed climbing the Antarctic slopes and devouring much of the bottom level of the food chain.[9]

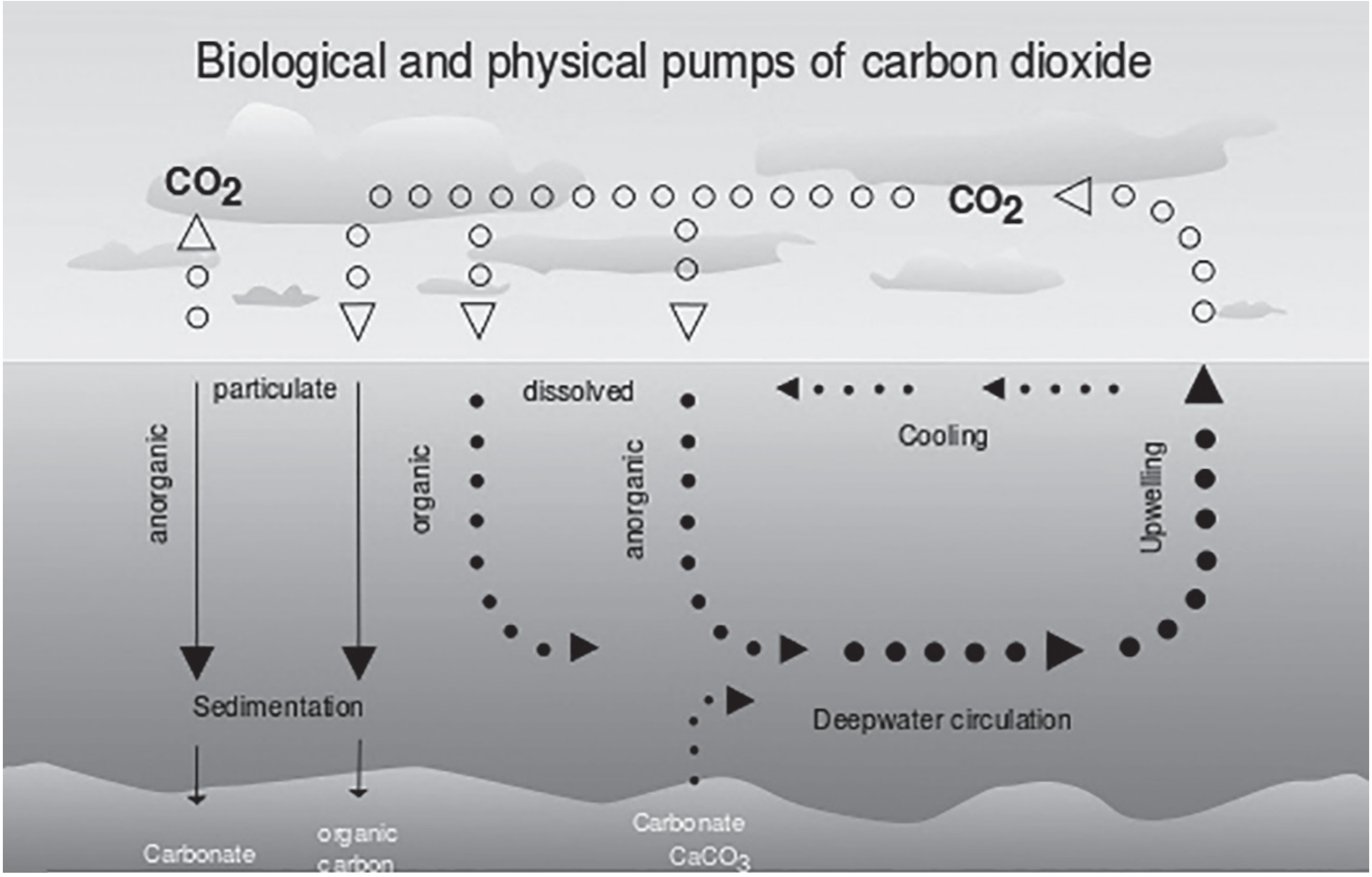
Volcanic deep-sea vents

Volcanic deep-sea vents tend to be highly acidic and may be as hot as 400°C. They are characterised by the absence of calcifying shellfish. Studies at a much shallower volcanic vent near Castello Aragonese, west of Naples, which is continually subjected to CO_2 bubbling up from the depths, give a good idea of the effects of low alkalinity on ocean life.[10] While there may be diatoms, phytoplankton sporting a silica shell in surface waters close to shallow vents, the sea water is too acidic to permit the forming of aragonite or calcium carbonate shells or of corals. In fact, subjecting tiny shellfish such as sea butterflies to seawater of pH 7.8 (still more alkaline than tap-water) can lead to buckling and deformation of their hair thin shells.[11] Low alkalinity even affects non-calcifying organisms, such as the semen of lugworms, common near British coasts, when in combination with copper pollution.[12]

The magnitude of the threat

If CO_2 emissions continue to follow a 'business-as-usual' scenario, marine scientists expect the alkalinity of the oceans to decrease to pH 7.8, the figure of the sea butterfly test above, by the end of the century, i.e. less alkaline by 150% (the pH scale is logarithmic). The fact that the sea water is warming is not good news for other oceanic creatures either. Many people will have read about coral bleaching. This refers to the dying of a range of algae, which live in symbiosis with corals; even a slight warming is fatal for many species. As to the effect of a high CO_2 environment on reefs, this is how the Intergovernmental Panel on Climate Change puts it: "Ocean acidification poses substantial risks to marine ecosystems, especially polar ecosystems and coral reefs, associated with impacts on the physiology, behavior, and population





Air-sea exchange of CO_2, (Creative Commons CC-BY-SA-2.5, original Hannes Grobe, August 2006 (UTC), Alfred Wegener Institute for Polar and Marine Research)

dynamics of individual species from phytoplankton to animals. Calcified molluscs, echinoderms, and reef-building corals are more sensitive than crustaceans (high confidence) and fishes (low confidence), with potentially detrimental consequences for fisheries and livelihoods."[13]

Protecting the 'whale pump'

Can something be done to mitigate the consequences of ocean acidification? There have been attempts to sow the ocean with iron filings or crushed olivine to boost diatom growth. Before resorting to unproven techno-fixes, we should protect what Roman and McCarthy call 'the whale pump'. Whales and other cetaceans feed near the seafloor, bringing nutrient-rich matter back to the surface in their excrement, which tends to remain in suspension near the surface in the form of a faecal plume.[14]

These nutrients are consumed by phytoplankton, allowing them to thrive. In addition, the huge whale skeletons, sunk to the ocean floor, store impressive amounts of carbon and nutrients, while providing shelter. Although the decline of baleen and sperm whales is well over 66%, Roman and McCarthy think recovery is still possible and would be of huge benefit for the oceanic ecosystem: "Dozens, possibly hundreds, of species depend on these whale falls in the deep sea," The more whales are valued and protected, the greater the gain for biodiversity. Roman and colleagues even speak of whales as "marine ecosystem engineers" in their latest paper.[15] If we want to preserve ocean health, the world needs more whale sanctuaries in addition to the two existing ones[16] as well as a permanent ban on commercial whaling and a firm commitment to limit greenhouse gas emissions.

Dr Wiebina Heesterman has degrees in information science, IT and human rights law and has studied different aspects of climate change while in retirement.

References

1. WWF (undated). Sustainable Seafood. www.worldwildlife.org/industries/sustainable-seafood
2. UN Food and Agriculture Organization (2005). Many of the world's poorest people depend on fish. www.fao.org
3. p.200 of: Kolbert E (2011). The Acid Sea. National Geographic, vol.219, no.4, pp.100-103
4. UNFCCC (2015). globaloceanforumdotcom.files.wordpress.com/2015/11/cop21-agenda_11-10.pdf
5. p.132 of: McClintock J (2012). Lost Antarctica: Adventures in a disappearing land. London: Palgrave Macmillan.
6. National Oceanic and Atmospheric Administration (2014). What are phytoplankton? oceanservice.noaa.gov/facts/phyto.html
7. pp.70,172 of: McClintock (2012). Op.cit.
8. Ibid: p.39
9. Ibid: pp.119, 141-161
10. pp.111-124 of: Kolbert E (2014). The sixth extinction: an unnatural history. London: Bloomsbury Publishing.
11. p.119 of McClintock (2012). Op.cit.
12. Waldbusser GG et al (2013). Ocean acidification killing oysters by inhibiting shell formation. Geophysical Research Letters, vol.40, no.10, pp.2171-2176.
13. p.17 of: Intergovernmental Panel on Climate Change (2014). Climate Change 2014: Impacts, Adaptation and Vulnerability. Summary for Policymakers. www.ipcc.ch/report/ar5/index.shtml
14. Roman J, McCarthy J (2010). The whale pump: marine mammals enhance productivity in a coastal basin. Plos ONE, vol.5, no.10. www.plosone.org/article/info
15. Roman J et al (2014). Whales as marine ecosystem engineers. Frontiers in Ecology and the Environment, vol.12, no.7, pp.377-385. www.esajournals.org/doi/abs/10.1890/130220
16. International Whaling Commission. Establishment of the International Whaling Commission's Sanctuaries. iwc.int/sanctuaries

Statistically assessing of the risks of commercial nuclear energy

As we approach the 30th anniversary of the Chernobyl disaster, Spencer Wheatley, Benjamin Sovacool and Didier Sornette argue that the risks of another major nuclear accident are much greater than the industry believes.

We recently performed a statistical study of the risk of accidents and incidents (events) occurring in nuclear power plants across the world.[1,2] Here some of the findings of this study, as well as references that it contains, are discussed as they pertain to the current and near-term risks.

Gathering nuclear accident data

The accident at Fukushima in 2011 – which is expected to cost at least 170 Billion US Dollars – brought again the issue of the safety of nuclear power generation to the attention of the public. Unsatisfied with the perceived overly optimistic risk assessments provided by the industry, both academia and the media attempted to provide some kind of assessment. A main obstacle in such studies is the fact that the industry regulator (the International Atomic Energy Agency, IAEA) does not publish data about historical accidents. Further, when the IAEA does publish a measure of the size of an event, it does so with the crude International Nuclear Event Scale (INES), a discrete seven point scale. To overcome this, we scoured the academic literature, news, and industry publications to compile a dataset of 184 events (from 1950 to 2014) with severity defined as the total resulting loss in inflation-adjusted US Dollars. This measure enables the holistic comparison of a variety of different types of events. To enable robust future studies of the risk of nuclear power the dataset has been published online with the public encouraged to review and recommend improvements.[3]

How likely is another Chernobyl or Fukushima?

We performed a statistical analysis of this data (namely the events with severity in excess of 20 million US Dollars), which is summarized within figure 1 (see reference 1 for the full account). The left panel of the figure concerns the frequency of events per reactor per year. For this, the observed rate of events was calculated both running backwards and forwards from the Chernobyl accident in 1986. The main observation here is that the frequency of accidents dropped substantially after Chernobyl, and has remained relatively constant since.[4] This drop was likely due to improvements in both technology and practices. The right panel of the figure concerns the severity of events. More specifically, the sample of events in excess of 20 million US Dollars (USD) both before and after the accident at Three Mile Island (TMI) in 1979, are plotted according to their complementary cumulative distribution function (CCDF) – a function that helps determine the probability that an event is in excess of a given size. The main observation is that, since TMI, moderate to large events have been less common. This is good news, but not an adequate improvement: the post-TMI distribution is so heavy tailed that the expected severity is mathematically infinite. This is reflected by the fact that the severity of Fukushima is larger than the sum of all remaining events. This point cannot be emphasized enough, as it implies that, if one wants to reduce the total risk level, one needs to effectively exclude the possibility of the most extreme events. Put simply, we need to move to a situation where major nuclear accidents are virtually impossible.

Given the statistical analysis of the historical data, we provide a characterization of the current (and near-term) risk level that is valid as long as the operational

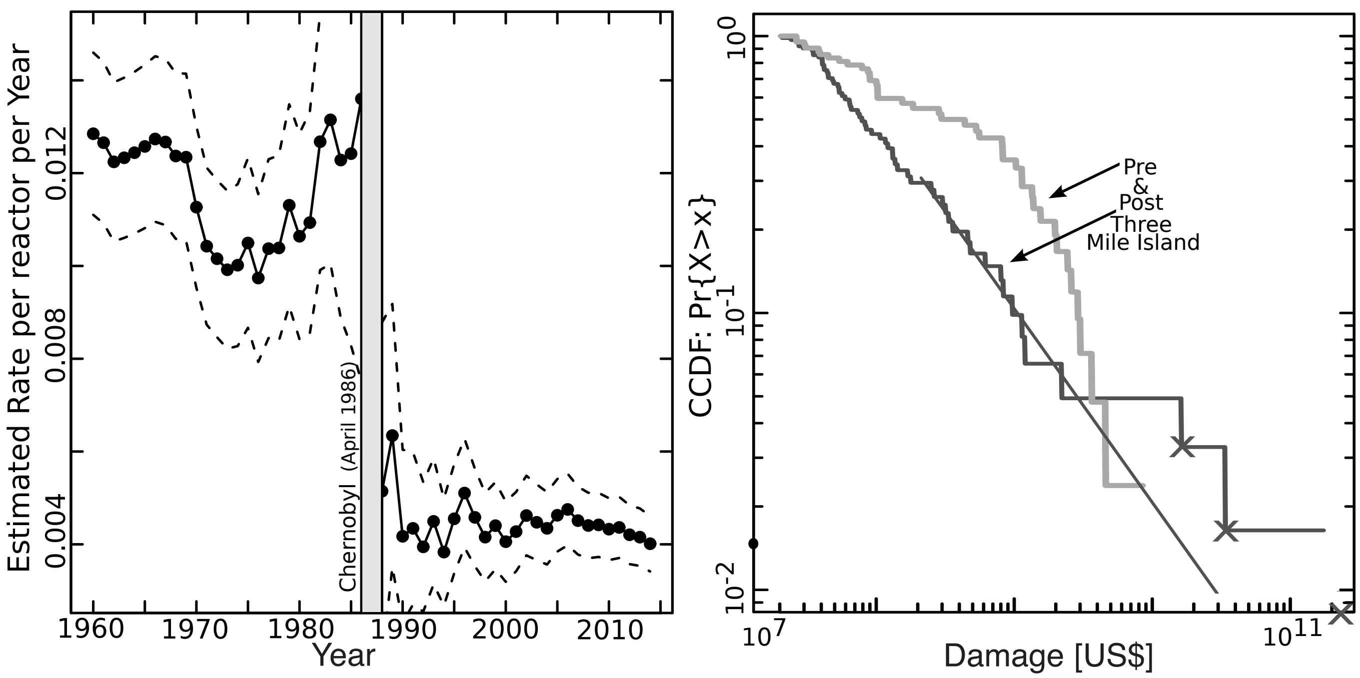


Figure 1. Left panel: the rate of events per reactor per year, where the estimates were taken running forward and backward from Chernobyl and are bounded by one Poisson standard error. Right panel: The damage/consequences in the pre and post Three Mile Island periods (light and dark, respectively) plotted according to their complementary cumulative distribution functions (CCDF).

fleet of reactors is well represented by the current fleet. Our first result is that one should expect about one event per year causing damage in excess of 20 Million USD. Next, to compute expected annual losses, we must assume a finite maximum loss. If we accept that the Fukushima event represents the largest possible damage, then the mean yearly loss is approximately 1.5 Billion USD with a standard error of 8 Billion USD. This brackets the construction cost of a large nuclear plant, suggesting that about one full equivalent nuclear power plant value could be lost each year on average.

If we are less optimistic and assume that the largest possible damage is about 10 times that of the estimated damage of Fukushima, then the average yearly loss is about 5.5 Billion USD with a very large dispersion of 55 Billion USD. Concerning the probability of the most extreme accidents, we have computed the 50% probability return periods for such events.[5] Hence we estimate that there is at least a 50% probability of a Chernobyl-type event (causing about 32 Billion USD in damage costs) happening in the next 30-60 years. We further estimate that there is at least a 50% probability of a Fukushima-type event (170 Billion USD) happening in the next 65-150 years.[6] Having a standard error of about 50%, these estimates are highly uncertain, but what is certain is that they are much larger than what industry estimates would suggest.

Reducing the risks

Given the high risk level, and the insufficient effectiveness of past improvements, changes that will effectively truncate the risk of extreme events are necessary. Responses following the Fukushima event may have some impact, but this remains to be seen. Further, the implementation of passive safety systems is certainly a step in the right direction. However, given the current risk level, the importance of low-carbon energy sources, and that we are already committed to the stewardship of five decades' worth of slowly decaying nuclear waste, it is clear that a significantly increased effort is needed to improve the state of nuclear technology.[7] Further, the authors strongly suggest that the industry publish a public dataset of nuclear accidents using a variety of precise and objective scientific measures such as radiation released and property damage caused. This would enable the best possible assessment of the risk, and better informed and more confident decision-making about energy policy.

Spencer Wheatley is a PhD student, and Prof. Didier Sornette his supervisor and Professor of the Chair of Entrepreneurial Risks at the Department of Management, Technology and Economics, ETH Zurich, Switzerland. Prof. Benjamin K. Sovacool is Professor of Business and Social Sciences at Aarhus University, Denmark, as well as Professor of Energy Policy at the Science Policy Research Unit (SPRU) at the University of Sussex, United Kingdom.

e-mails: swheatley@ethz.ch, BenjaminSo@hih.au.dk and dsornette@ethz.ch

Notes and references

1. Wheatley S, Sovacool B, Sornette D (2015). Of Disasters and Dragon Kings: A Statistical Analysis of Nuclear Power Incidents and Accidents. arXiv preprint arXiv:1504.02380
2. Wheatley S, Sovacool B, Sornette D (2016). Of Disasters and Dragon Kings: A Statistical Analysis of Nuclear Power Incidents and Accidents. Risk Analysis (in press).
3. Data published at: https://tasmania.ethz.ch/index.php/Nuclear_events_database.
4. Not visible here is that the rate dropped from the 1960s until Chernobyl. The high observed frequency in the 1960s and 1970s for the small number of operating reactors has little influence on the cumulative estimate.
5. The time period such that the probability of observing at least one event in excess of the given size is 0.5.
6. The range of estimates is given for parameter values ranging from moderately conservative to optimistic.
7. Sornette D (2015). A civil super-Apollo project in nuclear research for a safer and prosperous world. Energy Research and Social Science, vol.8, pp.60-65.

The Paris Agreement: key points

Stuart Parkinson, SGR

Amid great fanfare on 12th December 2015, delegates from 195 countries adopted the Paris Agreement on climate change.[1] Its three main aims are:

1. To keep the global temperature increase to "well below 2°C" and to "pursue efforts to limit the temperature increase to 1.5°C";
2. To increase the ability to adapt to the adverse impacts of climate change; and
3. To create the financial flows necessary to achieve (1) and (2).

The Agreement includes a number of provisions for achieving these aims, some overarching ones which are legally binding, and some more specific ones which are voluntary. Key among these provisions are:

- The aim for a "global peaking of greenhouse gas emissions as soon as possible", moving to a "balance" between emission sources and sinks "in the second half of this century";
- Voluntary target levels for national emissions (called "nationally determined contributions") – and the policies and plans to support them – that are to be reviewed and updated every five years (starting in 2018), and with each set of targets to be more stringent than the previous ones;
- National plans for adaptation to the impacts of climate change;
- Processes to support transparency in national reporting;
- A mechanism for dealing with "loss and damage" arising from climate change; and
- Legal obligations on industrialised countries to provide financial assistance to developing countries for mitigating emissions and adapting to impacts, with a voluntary collective target reaching $100 billion per year by 2020, and continuing above that level until at least 2025.

Is this enough to prevent "dangerous climate change"? Current voluntary national targets are putting us on course to about 2.7°C of warming.[2] The provisions in the Agreement have the potential to help shift the world on to a course for "well below 2°C" – but it will take considerably more effort by governments, businesses and civil society for that goal to be reached.

Dr Stuart Parkinson is Executive Director of SGR and has written widely on energy and climate issues.

References

1. UN FCCC (2015). Adoption of the Paris Agreement. FCCC/CP/2015/L.9/Rev.1. http://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf
2. Climate Analytics (2015). http://climateanalytics.org/publications/2015/indcs-lower-projected-warming-to-2-7-c-significant-progress-but-still-above-2oc

Science4Society Week: SGR's latest science education project

Jan Maskell, SGR, describes the activities for young people which our organisation undertook as part of its first Science4Society Week in 2015 – and looks at what is planned for March 2016.

How do you get students interested in some of the ethical issues to do with science, design and technology? Our Science4Society Week aims to do this through a range of inspiring activities – and in our first year the focus was on secondary school pupils. We worked closely with teachers, especially at Dallam School in south Cumbria, to design a framework of activities which were then delivered to about 1,000 students during a week in late March 2015. We are planning to expand on these for March 2016.

A whole school framework of activities

The structure of the framework began with all pupils exploring the definitions of 'science' and 'technology' as well as the concepts of 'ethical science' and 'technology justice' in their tutorial session. This provided a foundation of these concepts to enable them to apply some of their ideas to other lessons during the week.

Discussions about 'ethical science' covered what scientists do in their work and how values can influence this. Technology justice has been defined as where "everyone has the right to access the technologies they need to live the life they value, without limiting the ability of others now and in the future to do the same". By breaking this definition down into different sections, students were able to deconstruct the ideas underpinning what, for many, is a novel concept. Students were asked to apply, and reflect on, some of these ideas during their science, design and technology classes during the week.

Year 7 and 8 pupils (ages 11 to 13) participated in three specially designed lessons to include a debate or discussion, a problem solving activity and a practical workshop. These aimed to appeal to different preferences for and approaches to learning and to build on the content and outcomes from each lesson.

Debates, problem-solving and practical activities

The debate used a tried and tested process for a structured debate on a controversial topic, in this case: 'Should all new mobile phones be taxed so they are at least twice their recommended price?' The different 'rounds' of the debate helped students think through the issues – such as environmental impacts – and reconsider their opinions. The structure also showed them how to think about different ethical points of view, build a discussion and back up their opinions with facts. How students' opinions changed was recorded at the beginning, middle and end of the discussion – and it was possible to see that as a result of the discussion many pupils had changed their minds. One teacher commented about the debate, "I didn't know what to expect – but they came up with some really good ideas!"

In the second lesson (see example in photo above), after looking at different ways of generating renewable energy, small groups were asked to consider the variety of options available to the different communities living on a fictitious island. By assessing the potential generation options, the communities needs and the geographical features of the island, students were able to select the most appropriate technology. One teacher commented that these were "good resources and materials for students to consider".

By way of contrast, the third lesson was a very practical one, with the task of designing a simple wind turbine capable of lifting a weighted cup off the floor – with the winning team being the one producing a machine that lifts the most weight. One teacher commented that the pupils "were excited by challenge" while another said "The construction phase was engaging and pupils worked well in small groups – suggesting ideas and listening to ideas of others."

The outline of the whole school framework, as well as lesson plans, slides, video clips and resources were all made readily available and downloadable from the SGR website as a comprehensive package (see below). All of the activities are designed to integrate with the national curriculum.

Visits to eco-projects

As well as lessons during the normal school timetable, SGR helped school teachers and university lecturers organise visits for their students to locations where they could see in action examples of community-run renewable energy projects, super-insulated eco-homes, and innovative sharing schemes, such as cohousing and car clubs. "It was wonderful that they could see practical applications for solar, biomass and hydro power" said one teacher after a tour.

Science4Society Week was organised by SGR and, unlike many high-profile science education activities, it was not funded by any arms or fossil fuel corporations, just a group of charitable trusts.

On to 2016...

Science4Society Week 2016 will run from 14th to 20th March. We plan to repeat all the activities described above, but also include a new competition to 'Design an Eco-Community' and training sessions for educators in advance of the activity week. There will also be many more downloadable resources on a range of topics focusing on themes of energy, transport, buildings, food, healthcare, industry and water.

All education materials and other information on Science4Society Week can be downloaded from the SGR website at: http://www.sgr.org.uk/projects/science4society-week

Dr Jan Maskell is SGR's vice-chair and co-ordinator of Science4Society Week. She is a chartered psychologist.

25 years of science ethics at Cambridge

Richard Jennings, University of Cambridge, reflects on lessons learned from the teaching of science ethics at one of the UK's leading universities.

In 1990, I gave my first lectures on 'Ethics in Science' at the University of Cambridge. I continued to give these lectures, with variations and developments, of course, for the next 20 years. Five years ago I retired from lecturing, and passed the course on to my colleague Dr Steven John, who still continues the tradition, though now under the heading of 'Philosophy of Science in Practice'.

A gap in the teaching of philosophy of science

At the time I began this series of lectures I had already been lecturing for some ten years on philosophy of science. The two main philosophical areas we covered were epistemology and metaphysics – e.g. how, and to what degree, we can have scientific knowledge; and whether this knowledge tells us how the world really is or simply provides a useful way of making predictions. I began to realise that these lectures did not include any of the ethical issues that arise in science, and I felt that this was a gap that needed to be filled. The lectures that I was giving were addressed to second year undergraduate students in natural science who had decided to study History and Philosophy of Science (HPS) as one of their three options for the second year natural science course. I felt that in addition to these basic philosophical issues, the students would benefit from exposure to the ethical issues that arise in science. Also, by this time, largely due to the influence of various forms of social studies of science, philosophers of science were increasingly aware of the social context in which science was practised.

Classifying ethical issues in science

Looking at the variety of ethical issues that arise in science, I felt there needed to be some way of organising the issues – some typology, or structure. Over time I gathered three large files of ethical issues in science, including various kinds of fraud, the use of animals in experiments, the use of science in military applications, and, politically, how science was and should be funded. I struggled with how to categorise the variety of issues.

I wanted to provide lectures that would be relevant to my audience. My audience consisted of students from the whole spectrum of the natural sciences, from theoretical physics through chemistry and various biological subjects, to experimental psychology. Because my audience was drawn from this spectrum of natural science subjects I decided not to get involved with medical ethics. However, I found that there were a number of issues that were relevant to all sciences. One was the problem of fraud. By the early 1990s the incidence of fraud in science was becoming more evident, and various surveys had been carried out which documented this. I thought it important that young scientists be aware that there is fraud, and I wanted to explain, among other things, that, even if they don't adopt the time saving strategy of making up their empirical results, they should still resist the temptation to present results as better than they are.

Another issue that would affect all of the students was that of funding – how, and on what basis, science is funded. In 1993 the then Conservative government published a White paper, *Realising our potential: a strategy for science, engineering and technology*.[1] This provided a ready source of policy insight which would be of value to the students as they moved on in their careers. It also proved a rich source of quotations, such as "Our specific policies are designed to get maximum value for money from our annual public expenditure of some £6 billion on science and technology." (p.5)

But what I found was that the most pressing ethical issues that arise in science are in the applications of science – and the issues that arise do depend on particular sciences. So, for example, the military uses of science tend to be drawn from physics, while the science used in genetically modified organisms is biological, and the uses of science in advertising are drawn from psychology. Also, during the time I was teaching this course, the animal rights movement became very prominent, and I saw that this was a different kind of problem – not so much a problem in the use of science but in how science is carried out. I was still struggling with the problem of categorising the ethical issues that arise in science.

Three types of ethical issues in science

Over time I began to see a way to classify the ethical issues in science. I saw that fraud was one major kind of ethical issue ('Responsible conduct of research' in the US), and that the ethical issues arising in the application of science were of a different kind. But I also saw that there were ethical issues in how science was carried out. Using animals raised issues, but these were not issues of fraud nor of application of science. It then occurred to me that the use of animals and of human beings were similar in that both involved using sentient beings who could suffer, and that this was a third kind of ethical issue that the scientist may face.

So, in the end, I came up with a tri-partite classification of the kinds of ethical decisions which the scientist may face – those involving fraud, those involving the use of sentient beings, and those involving the application of their scientific knowledge. Policy and funding decisions are not decisions that the scientist makes, but decisions that affect the scientist. Nonetheless, policy and funding decisions (e.g. whether to fund research into renewable energy or into nuclear energy) are still ethical issues. And even though these are not decisions the scientist makes, the scientist still has to decide whether to take the funding and carry out the research.

Dr Richard Jennings is a Director of Studies at the Department of History and Philosophy of Science, University of Cambridge.

Reference

1. HM Government (1993). www.gov.uk/government/publications/realising-our-potential-a-strategy-for-science-engineering-and-technology

The industrialisation of war: lessons from World War I

Stuart Parkinson, SGR, examines how technological innovation contributed to one of the most devastating wars in human history – and asks what lessons we should take from this.

2016 is the centenary of two of the bloodiest battles of World War I: the Somme and Verdun. And WWI itself is one of the most destructive wars in human history. As an example of the carnage, the total death toll of the war has been estimated at over 15 million people between July 1914 and November 1918 – an average of about 3.5m per year. Only the Russian Civil War and World War II had higher annual death rates.[1,2] The centenary is therefore an important opportunity to reflect on a conflict in which rapid developments in technology led to a huge increase in the devastation that could be caused by war.

In this article, I examine which technological developments led to the most casualties and what lessons we can draw about science, technology and the military today.

Harnessing the Industrial Revolution for war

The late 18th and 19th centuries saw a rapid development in technology which we now, of course, refer to as the Industrial Revolution. Starting in Europe, major developments transformed a wide range of industries. Growing exploitation of minerals like coal and iron were especially important, as was the advent of the steam engine – especially in ships and trains.

It was not long before the military started harnessing some of these inventions. Mass production in factories churned out not only large numbers of standardised guns and bullets, but also boots, uniforms and tents.[3] The guns were more reliable and hence more accurate. A bullet was 30 times more likely to strike its target. Developments in transport were also utilised, with steel becoming standard in battleships and trains starting to be used to quickly ferry large numbers of troops to war zones. Advances in chemistry led to new high explosives.

The first wars in which these new military technologies were used on a large scale included the Crimean War (1854-56) and the American Civil War (1861-65). Both of these provided a taster for the carnage of WWI, being characterised by trench warfare in which frontal assaults against well-defended positions led to massacres of infantry soldiers.

Pre-1914 arms races

In the years running up to the outbreak of WWI, there were several key developments in military technologies that would lead to high casualties during the war itself.

Arguably the most important were new high explosives. Gunpowder had been the explosive of choice in war for around 500 years, but new developments in organic chemistry by Alfred Nobel and others led to new materials, initially used in mining. Further work in the late 19th century especially in Prussia/Germany, Britain and France refined the materials for use in hand-guns and artillery. Most successful were Poudre B and Cordite MD which burnt in such a way as to provide the required directed pressure needed to propel a projectile, without blowing up the weapon.[4]

Developments in gun manufacture were also crucial. Muskets were being replaced by rifles, which were more accurate. Machine guns were also brought onto the scene, first invented in the USA. By 1914, the most widely used machine gun was the British Maxim, capable of firing a shocking 666 rounds per minute.[5]

New artillery was also developed to use the new explosives. By the outbreak of WWI, a single shell weighing one tonne could be propelled more than 30 kilometres. However, smaller and more mobile guns were preferred as these could accurately fire a shell every three seconds.[6]

The development of weapons using poisonous gases was limited by the Hague peace conference of 1899. However, this only limited the development of the delivery systems rather than the gases themselves, in which Germany, Britain and France all had active research programmes.[7]

The development of the submarine and the torpedo would also prove to be crucial. Work in France and the USA led to the first successful military submarines, with Britain, Germany and Italy quickly commissioning their own. At the start of the 20th century, there were about 30 military submarines. This number would rapidly grow. The main weapon of the submarine immediately became the torpedo, invented in Britain. An early demonstration of the effectiveness of this weapon was in a Japanese attack on the Russian fleet in 1904. It was then rapidly deployed by all the major powers.[8]

The other major development in military technology that occurred in the years running up to 1914 was the steam-driven battleship. The first was the *Dreadnought*, launched by the British in 1906. Heavily armed and fast, it helped to cement Britain's naval dominance. However, other naval powers, especially Germany, developed their own more powerful battleships during a rapid naval arms race in the pre-war years.[9]

Helping to fuel these arms races were not just competition between national militaries and technological innovation, but also international commerce. Major private corporations such as Vickers and Armstrong in the UK and Krupp in Germany made huge profits from arms sales, including major contracts with governments which would later become the 'enemy'.[10]

Key technological developments during the war

After WWI broke out, in summer 1914, the pressure rapidly grew for the warring nations and their scientists and engineers to try to create 'military advantage' through innovation. The main areas were diverse, including trench construction, artillery and its targeting, poisonous gases, submarines, tanks and planes.

In terms of artillery, perhaps the most important development during the war was the scaling up of production of the heavy guns which had begun to be deployed by militaries before 1914. Many thousands of these weapons, such as the British 18 Pounder and the French 75mm, were produced.[11] Also important was the development of improved targeting – such as 'sound-ranging'. These developments led to artillery use on an unprecedented scale. For example, during the Meuse-Argonne campaign – part of the final Allied advance in 1918 – US forces were firing an incredible 40,000 tonnes of shells *each day*.[12]

Mass production also led to the machine gun being a widely used and devastating weapon, especially in defending trenches. For example, the British favoured the Lewis gun whose numbers increased nine-fold between 1915 and 1918.[13]

German research resulted in the first use of lethal gas in the war – in this case, chlorine – in April 1915.[14] Further development work led to Germany deploying phosgene and mustard gas later in the war. Britain's first use of lethal gas was in September 1915, although it never used it on the scale that Germany did. However, poisonous gases proved to have limited military value – due to their dependence on weather conditions and their countering through, for example, gas masks. Gases also proved to be significantly less lethal than more conventional weapons.[15]

There was rapid development of military aircraft during WWI, although their role in the conflict remained largely marginal.[16] Planes and airships were adapted to drop bombs, but their main role was reconnaissance, especially spotting the location of enemy artillery.

Submarine development also proceeded quickly during WWI. Germany, in particular, favoured this sort of weapons system, given British superiority in surface warships. By the war's end they had built 390 'U-boats', and used them to devastating effect, especially from early 1917 onwards when they resorted to 'unrestricted' submarine warfare to try to cut off Britain's maritime supply routes. About four million tonnes of shipping – much of it crewed by civilians – was sunk in little over a year.[17]

In military terms, arguably the most decisive new technology of the war was the tank. First deployed by Britain in 1916 with the aim of overrunning trenches defended by barbed wire and machine guns, it did not initially prove effective. However, further innovation and mass production led to Britain and France each deploying several hundred from the summer of 1918. They proved critical in driving back German forces.[18]

Which weapons were the biggest killers?

Estimating casualty rates in war is a notoriously difficult exercise, especially when analysing data from a century ago. Nevertheless, World War I historians and other researchers have uncovered a range of information which allows some assessment to be made of the most lethal technologies.

Overall, based on a range of sources, researcher Matthew White has estimated that approximately 8.5 million military personnel and around 6.5m civilians died in World War I.[19] Wikipedia researchers have provided comparable estimates.[20]

Within the military totals, the overwhelming majority of deaths (and injuries) were borne by armies, with naval deaths being only a few percent of the total.[21] Of land-based deaths, the evidence points to artillery being by far the leading cause, followed by machine guns. For example, historians Stephen Bull,[22] Gary Sheffield,[23] and Stephane Audoin-Rouzeau[24] quote a range of official figures that indicate between 50% and 85% of casualties on the battlefield were due to artillery fire.

Civilian deaths – which are much less certain – were overwhelmingly caused by malnutrition and disease, as a result of shortages due to the effect of battlefields, blockades and damage to infrastructure caused by the war. Hence, no single weapons system can be identified as the cause in those cases. Nevertheless, artillery and machine gun fire still resulted in large numbers of civilian casualties.

Drawing on sources already quoted, I estimate the following overall numbers of deaths due to different weapons systems. I must emphasise these have high levels of uncertainty.

- Artillery: 6m (5m military and 1m civilian)
- Machines guns: 3m (2m military and 1m civilian)
- Submarines; rifles: 0.5m each
- Tanks; chemical weapons; warships; planes: 0.1m each

A further 5m civilians are thought to have died due to malnutrition and disease.

Some lessons

Lessons from the carnage of the World War I continue to be hotly debated, but I want to offer some especially related to science and technology.

Historian John Keegan points out that there was rapid technological development in weapons systems in the years before WWI, in contrast to that in communications.[25] As such, the means to wage war on an unprecedented scale was readily at hand when the international political crisis struck in summer 1914, whereas technologies which political leaders could use to clarify and defuse the situation (e.g. high quality person-to-person phones) were not.

Today, the rapid pace of development in communications technologies is outpacing much in the military field – indicating that perhaps some lessons have been learned about the importance of communication in helping different peoples understand and trust one another. However, militaries are harnessing some of those communications technologies to help revolutionise warfare, an obvious example being the remote piloting of 'drones'. New international arms controls are urgently needed in this area.

This brings me to another key lesson. 100 years on from the Battle of the Somme, artillery is still being used to devastating effect in many parts of the world – with the carnage of the Syrian war being an obvious example. Campaigners are attempting to get their use restricted under existing international disarmament treaties, but governments are currently showing little interest.[26]

A further lesson concerns the international arms trade. A lack of controls in the years before WWI allowed private corporations to profit from arming both sides. While a new international Arms Trade Treaty was agreed in 2013, its currently weak provisions still allow a major trade which fuels war and repression across the world.[27]

The overarching conclusion is that allowing militaries to play a significant role in scientific research and technological development was a major driver of world war 100 years ago, and it still creates major dangers today. We need to prioritise using science and technology to support and strengthen disarmament processes across the world – that would be the best way of commemorating the fallen from the century past.

Dr Stuart Parkinson is Executive Director of Scientists for Global Responsibility, and has written widely on the links between science, technology and militarism.

Thanks to Daniel Cahn for valuable help with research for this article.

References

1. Figures and calculations based on data from: White M (2011). Atrocitology. Canongate, London. Death rate of World War II (1939-45): approx 6.5m/y; Russian Civil War (1918-20): approx 4m/y.
2. See also figures in: Wikipedia (2015). en.wikipedia.org/wiki/World_War_I_casualties
3. p295 of: White (2011) – as note 1.
4. Chap. 14 of: Williams T (1999). A history of invention: from stone axes to silicon chips. TimeWarner books.
5. As note 4.
6. As note 4.
7. Bull S (2014). Trench: A History of Trench Warfare on the Western Front. Osprey Publishing.
8. As note 4.
9. As note 4.
10. On the Record/ Campaign Against Arms Trade (2014). Arming All Sides. armingallsides.on-the-record.org.uk/
11. History Learning Site (undated). www.historylearningsite.co.uk/artillery_and_world_war_one.htm
12. McKenny J (2007). The Organizational History of Field Artillery: 1775-2003. US Government Printing Office.
13. Sheffield G (ed.) (2007). War on the Western Front. Osprey Publishing.
14. As note 7.
15. As note 7.
16. As note 4.
17. p.361 of: Keegan J (1998). The First World War. Random House.
18. As note 4.
19. As note 1.
20. As note 2.
21. As note 2.
22. As note 7.
23. As note 13.
24. Audoin-Rouzeau S (2012). Combat. Pp.173-187 in: Horne J (2012). A Companion to World War I. Blackwell Publishing Ltd.
25. As note 17.
26. Article 36 (2011). www.article36.org/explosive-weapons/introduction-explosive-weapons/
27. War Resisters International (2013). www.wri-irg.org/node/21654/

The quest for 'brain-like machines'

Michael Reinsborough, King's College London, discusses the leading international neuroscience projects and the growing interest of the military.

Are computers a biotechnology? One place from which the future of computing and robotics technologies is being thought about is a bit unexpected – the neuroscience lab. Over the past three years, a number of large research initiatives on the brain have been announced. Following the launch of the European Union's Human Brain Project (HBP)[1] and the BRAIN Initiative in the USA,[2] other large scale cross-laboratory collaborative initiatives have begun in Japan, Australia, Israel and now China. While each project varies in its objectives, one similarity is the emphasis on using computers to draw together large amounts of experimental brain data for analysis. Not only are computers being used to think about how the brain is organised, the brain is being used to think about how computers are organised – and there is a lot of interest.

Brain or computer?

The 86 billion neurons (up to 860 trillion synaptic interconnections) fitting neatly within the human skull, utilise 20 watts of power and can solve complex problems like recognising a face. In comparison, an exascale supercomputer – probably the size of a football field, and requiring the equivalent of a small coal-fired power station to run it – would be necessary to simulate this amount of neuronal interconnection.[3] Most visual or other pattern-matching tasks that are necessary for movement in an environment, and quite simple for a human, are beyond the capability of advanced computers and robots. Researchers who think the brain is comparable to a computer are very interested in learning from biology. One might even satirise some computer scientists as having 'brain envy'.

Of course, increasing our knowledge of the brain is potentially beneficial. On the medical side, the research could help to improve our mental health or our treatment of brain diseases.

Lesser known, however, are the possible benefits that neuroscience might bring to computing. Two examples are better pattern recognition and greater energy efficiency. Ever since Santiago Ramón y Cajal drew the first pictures of a neuron in the 1890s, scientists have tried to understand the electrical properties of our constantly changing brains. A key step was the 1952 discovery of the relationship between charge and ion exchange at the synaptic cleft between the neurons. The changing relationship between neurons was simplified by Carla Shatz in 1992 as 'what fires together wires together'. This neural plasticity allows the brain to strengthen links that acknowledge patterns in its environment.

This same principle is emulated when building neuromorphic computer chips – chips that mimic the decentralised memory and unusual firing patterns of the brain. Since much energy lost in computing happens in the distance between the memory storage location and the central processor, a decentralised structure of memory stored in or near the relationships of firing patterns that carry out simple calculations can be more energy efficient. This is crucial for supercomputers.

Military interest

While most funding for the leading brain projects comes from civilian (especially medical) research budgets, it is important to realise that there is also military interest. In the USA, the Defense Advanced Research Projects Agency (DARPA) is one of several agencies providing the overall budget for the BRAIN Initiative. DARPA's goals are primarily in relation to veterans' after-combat mental health, but there is also interest in enhancing the combat effectiveness of soldiers. In the EU, all funding for the HBP comes from a science budget earmarked to develop innovation in and improve the competitiveness of the EU computer industry. Specifically the HBP does not accept military research funding.

Many advances in science and neuroscience (regardless of how they were funded) have resulted in applications with both military and civilian use. For example, shortly after acetylcholine was discovered to be a neurotransmitter, the G-series of nerve agents (including sarin) were discovered during civilian research into pesticides. Other civilian discoveries led to the more deadly V-series, as well as the development of 'incapacitants' (also potentially lethal). Early warnings from researchers in neurotoxicity helped raise the alarm. Work since has limited their use according to international law, but with very poor verification and enforcement mechanisms.

There are parallels here with current research in artificial intelligence. 'Brain-like machines' are likely to have numerous civilian applications – for example, self-driving cars and medical informatics. Their development may also directly or indirectly lead to complex autonomous weapons systems and new potentials for intelligence gathering and other surveillance. While some science fiction imaginings for artificial intelligence are either not possible or a long way off, there are still clearly many serious causes for concern.

The International Committee for Robot Arms Control[4] and other initiatives are presently pushing for international treaties to prevent advances in drone warfare. But, in addition to the vigilance of individual scientists, we must continue to challenge the commercial, military and government institutions to be open and accountable.

Dr Michael Reinsborough is a Research Associate at King's College, London, where he contributes to the Human Brain Project.

References

1. www.humanbrainproject.eu/discover/the-project/overview
2. www.braininitiative.nih.gov/about/newg.htm
3. An exaflop is a billion billion floating point calculations per second, a thousand-fold increase in the performance of the first petascale computer developed in 2008.
4. icrac.net/who

Flights from sense: how space tourism could alter the climate

Philip Chapman investigates the potential environmental impacts should space tourism recover from its recent setbacks and become a thriving global industry.

It is over a year since the high altitude disintegration of Virgin Galactic's SpaceShipTwo (SS2) – which caused the tragic death of pilot Mike Alsbury. The mission had been a test flight of what Virgin still hopes will become regularly scheduled tourist trips into space. While the cause of the crash has now been established as pilot error, made possible by the failure of the contractor responsible to safeguard against its occurrence,[1] immediate media coverage of the crash did include voices calling for Virgin to quit the space business because of alleged incompetence.[2] However, none of the coverage has mentioned the impact that the industry would have on the global climate were this type of spacecraft ever to make frequent space tourism a reality. The particular concern is due to a new dirtier type of rocket engine, the 'hybrid', which, if deployed on a large-scale, would soon start polluting the stratosphere and creating a low density cloud of soot that would span the globe. Establishing exactly how this stratospheric 'black carbon' will affect the climate system will require further investigation, but the sole scientific study to do so thus far has given alarming results.

Space tourism using conventional rockets

American multi-millionaire Dennis Tito became the first space tourist when he flew to the International Space Station (ISS) aboard a Russian Soyuz-TM spacecraft in 2001. His flight was organised through a US company called Space Adventures, the only company to have sent tourists into space thus far and sending only seven in total before the Russians suspended the use of its spacecraft for tourists. Space Adventures continues however to promise a return of tourists to the ISS using another variant of the Soyuz spacecraft and using Boeing's Commercial Space Transportation-100 craft.[3]

This venture represents part of the consequences of NASA's boost to the commercial sector by retiring the Space Shuttle and concentrating its vessel development on deeper space. Accordingly, the NASA Authorization Act of 2010 provided $1.6 billion for private companies to develop human spaceflight capabilities, under which NASA has drawn up an 'Integrated Design Contract' (IDC). This means that multiple companies will be developing 'end-to-end' capabilities, i.e. spacecraft, launch vehicles, ground control, recovery capacity and all the services and add-ons necessary for sending people into low earth orbit. And just as Boeing has done, other commercial ventures should be expected to solicit private as well as state customers in the future. There are also a number of companies promising to send tourists into orbit independent of any funding from NASA.[4]

Sub-orbital space tourism

It is other types of space tourism however that (at least until the recent crash) have had a greater immediate prospect of expanding rapidly, largely because they do not depend upon low earth orbit infrastructure, such as the ISS, in order to operate.

Suborbital flights technically enter outer space because they cross the Kármán line, defined as above 100km above the Earth's surface. It is this sector of the industry that has been set for imminent expansion. There are a number of companies presently developing craft capable of suborbital flight and promising to take tourists on flights in the coming years. One of these, XCOR, based in California, is developing the Lynx suborbital spacecraft with a single passenger seat. The craft will take off and land horizontally, and the company plans that it would eventually make several suborbital flights per day.[5] Enabling this relative simplicity in turnaround is the fact that, like most other rocket engines, including the Soyuz, the Lynx craft will burn a mixture of liquid oxygen and kerosene.

In contrast to this 'typical' engine is that of the spacecraft belonging to the most widely publicised space tourism venture – the one emblazoned with the Virgin brand. Virgin Galactic's SpaceShipTwo is equipped with a single hybrid rocket motor. In the world of rocket engines however, 'hybrid' does not mean that its hydrocarbon-fuelled propulsion system is supplemented by an electric motor, as in a hybrid car. Rather hybrid here describes the use of fuel in different states of matter. Until mid-2014 that meant for SS2's engine the fuel was solid synthetic hydroxyl-terminated polybutadiene and liquid nitrous oxide (basically, rubber and laughing gas). This engine had a number of problems during tests and was deemed unable to provide sufficient power to take the craft to the desired height. The subcontractor responsible suggested reducing the number of passengers on SS2 to four, but Virgin apparently determined that it could not make money under such circumstances.[6] They decided instead to use a different hybrid engine developed by the principal contractor, Scaled Composites, which burns a thermoplastic rather than rubber.

Unlike the Lynx craft, SS2 is air-launched, meaning it is dependent upon a mothership, in this case a cargo vessel called WhiteKnightTwo (WK2). SS2 launches from WK2 at 15.5km before firing its engine for approximately 70 seconds and attaining speeds of close to 4,000km/h. The plan is that it will then coast up to 110km where it will spend 5 minutes in the weightlessness of space before beginning to descend. SS2 thus launches from its mothership close to the tropopause (the top of the troposhere) before flying through the stratosphere and mesosphere and will just cross the Kármán line into outer space. Its engine will therefore burn within the stratosphere and it is here that its emission of black carbon will provide the most atmospheric altering effects of the entire endeavour.

Impacts on the atmosphere and climate

The stratosphere is the section of the atmosphere where the ozone layer resides and it is this layer that causes the effects that creates the zone. Whereas below the tropopause (from the Earth's surface up to the bottom of the stratosphere) temperature falls with increasing altitude, above it there is an inversion; in the stratosphere temperature increases with altitude because ozone absorbs shortwave radiation from the sun. The temperature inversion creates a stable density structure in the stratosphere and the overturning circulation that occurs here is therefore slow (see Figure 1). Coupled with low moisture content this means that no clouds form and there is therefore no rain. These factors, along with the low density that reduces coagulation, mean that particles emitted here have a residence time of years, rather than the weeks they would have in the troposphere.[7]

This in large part is why Darin Toohey, professor of atmospheric and ocean sciences at the University of Colorado, says "there's one issue and it's simple: you don't want to put black carbon in the stratosphere. Period."[9]

The results of the 2010 modelling study that Toohey co-authored showed a non-uniform effect over the globe of sustained regular launches of these spacecraft.[10] Assuming a launch site at a latitude of

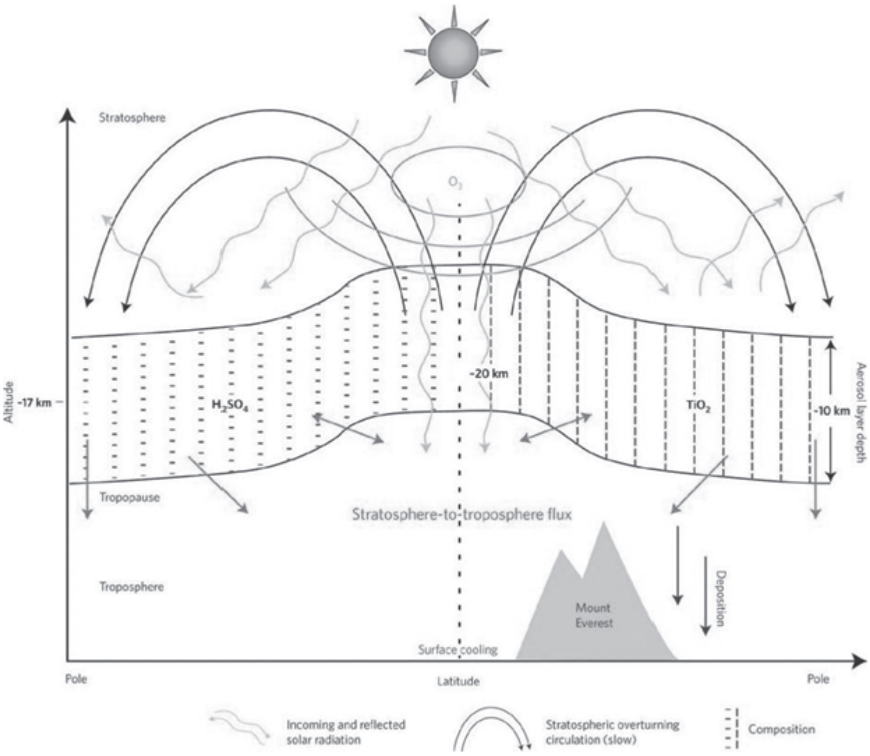


Figure 1. The slow overturning circulation in the stratosphere that covers the globe.[8]

about 33°N (in line with where Virgin Galactic's Spaceport America has been built), the majority of the black carbon (BC) was constrained between 25°N and 45°N and only about 20% of the pollutant travelled into the southern hemisphere. This asymmetry could be the driver of the resultant modelled decrease of ozone at the tropics and sub-tropics but an increase at the poles. This altered distribution of ozone has been attributed to greater stratospheric overturning circulation in previous studies, which has been shown to be produced by relatively small differential heating effects in the stratosphere. Within the northern hemisphere stratospheric zone, where most of the BC was distributed, temperature increased by approximately 0.2°C whereas, because very little BC went into the southern hemisphere, there was no heating there. This suggests that the latitude of the launch site may play an important role in the effect on ozone distribution, which was found to reduce ozone in the tropics by the same amount as CFCs have caused. The increase in the stratospheric circulation caused by the BC load is found to be roughly equivalent to the changes induced in this circulation due to modelled greenhouse gas emissions.

Modelled temperature changes at the surface also differed regionally and seasonally, with up to a 1°C increase at the poles,[11] but taken together show BC from 1,000 launches per year would influence global climate by about the same amount as the entire current global aviation industry, with a radiative forcing effect of 43mW/m^2. Also of note is that the climate change effect of the emitted BC exceeds the climate change effect of the emitted carbon dioxide by a factor of about 100,000. When Virgin Galactic boast about the low CO_2 emissions from SS2 in comparison to other air travel,[12] they are missing the most significant climate impact their new fleet of machines is likely to have.

The University of Colorado study was the first to model the global climate impacts of the particle emissions by rockets and as a single study with many parameters only loosely constrained it is far from the final word on the subject. However, despite the money being poured into these high profile ventures and the scale of the impact they could have on the atmosphere, the calls of the authors for their work to be built upon and extended remain largely unanswered.

Time for more caution

Current knowledge of the atmosphere, coupled with the University of Colorado's recent modelling work, should be considered sufficient to suggest a course of considerable caution for space tourism, especially considering the huge greenhouse gas forcing that humans are already responsible for. It is only with the benefit of hindsight that the other global environmental impacts of many applications of the technological innovations of the industrial age are now known. But we can no longer claim to be ignorant of the risks of a free-for-all in the stratosphere. The current plans for space tourism look much more like a demonstration of reckless disregard for the future.

Philip Chapman studied marine biology and oceanography at Southampton University, and has recently been investigating coastal adaptation to rising sea levels in the global south in collaboration with Yale University. He also has a long-standing interest is space technology issues.

References

1. Space.com (2015). Deadly SpaceShipTwo Crash Caused by Co-Pilot Error: NTSB. www.space.com/30073-virgin-galactic-spaceshiptwo-crash-pilot-error.html
2. Daily Telegraph (2014). Virgin Galactic crash: Branson 'should stick to mobile phones' says expert. www.telegraph.co.uk/news/worldnews/northamerica/usa/11204425/Virgin-Galactic-crash-Branson-should-stick-to-mobile-phones-says-expert.html
3. SpaceNews (2010). Boeing Partners with Space Adventures to Market CST-100 Flights. www.spacenews.com/article/boeing-partners-space-adventures-market-cst-100-flights
4. Seedhouse E (2014). Tourists in Space: A Practical Guide. Springer.
5. New Scientist (2008). Rocket company offers $95,000 trips to space. www.newscientist.com/article/dn16185-rocket-company-offers-95000-trips-to-space.html Wikipedia (2016). XCOR Lynx. en.wikipedia.org/wiki/XCOR_Lynx
6. Wall Street Journal (2014). Problems Plagued Virgin Galactic Rocket Ship Long Before Crash. online.wsj.com/articles/problems-plagued-virgin-galactic-rocket-ship-long-before-crash-1415838171
7. Hinds W (2012). Aerosol Technology: Properties, Behavior, and Measurement of Airborne Particles. John Wiley & Sons.
8. Pope F et al (2012). Stratospheric aerosol particles and solar-radiation management. Nature Climate Change, vol.2, pp.713–719.
9. Popular Science (2013). Space Tourism's Black Carbon Problem. www.popsci.com/science/article/2013-05/space-tourism-experiment-geo-engineering
10. Ross M, Mills M, Toohey D (2010). Potential climate impact of black carbon emitted by rockets. Geophysical Research Letters, vol.37, no.24. DOI: 10.1029/2010GL044548
11. Nature News (2010). Space tourism to accelerate climate change. doi:10.1038/news.2010.558
12. Scientific American (2009). Can Space Travel Be Environmentally Friendly? www.scientificamerican.com/article/space-travel-environmentally-friendly-branson-virgin-galactic

Update

Since this article was written, there have been significant test flights of Blue Origin's New Shepard rocket and SpaceX's Falcon rocket, which indicate that these corporations may be gaining the upper hand in the space tourism industry. Although they do not use the more polluting engines favoured by Virgin Galactic, there nevertheless remains a question over their environmental credentials.

UK climate policy unravelling *– continued from front page*

of the highest performing countries for action on climate change by the NGO Germanwatch.[6] The NGO also pointed out that the UK's energy-related carbon emissions per head of population were now only slightly above those of China.

However, a closer look reveals a whole host of problems.

A lack of progress

The first set of problems can be identified from the CCC's progress report.[7] One particular issue was that a large proportion of recent reductions were due to little more than good luck. For example, warmer winter weather in 2014 had led to markedly reduced energy consumption, while a large drop in emissions in the industrial sector had been unexpected and still remains to be clearly explained. Such emissions reduction may be reversed if our luck does not continue to hold.

One area where progress had especially stalled was building energy efficiency. A key problem here had been the general failure of the Coalition government's Green Deal programme, introduced in 2012, whose shortcomings have been pointed out by numerous analysts, including SGR.[8] The scheme led to the annual rate of home energy efficiency installations falling by over 60% in the course of a single year, and the rate has continued to fall since.[9]

There has also been a general lack of progress in reducing emissions from the agricultural sector, while transport-related emissions actually rose slightly between 2013 and 2014.[10]

However, the CCC's biggest criticism was the general lack of longer term climate policy measures beyond 2020 – and even major proposals that the government had indicated its commitment to, such as new nuclear power stations, were subject to serious doubts about the industry's capability to deliver.

It is also important to remember that the CCC's remit is only to assess government policy against the targets set in the Climate Change Act – which is focused on an 80% reduction by 2050. The CCC has acknowledged that this only represents the UK's share in giving the world a 50% chance of staying below a 2°C global temperature rise. The new Paris Agreement (see p?) now specifies a target of "well below 2°C" with the need "to pursue efforts to limit the temperature increase to 1.5°C" – reflecting the latest scientific evidence that points to some major impacts below 2°C. Hence, it is clear that a great deal more ambition is needed by the UK (and other nations). Figures from the Tyndall Centre for Climate Change Research (complied before the Paris climate conference) suggest that a more acceptable target for the UK and EU would be at least 80% cuts by 2030 – 20 years earlier than in current legislation.[11]

Undoing the good work

The policy response since the new Conservative government came to power in May, however, has almost been the reverse of what is needed.

We have seen major cuts to financial and other support for renewable energy.[12,13] Subsidies for onshore wind farms are due to be abolished from spring 2016 and planning controls on wind turbines are being made more restrictive. Subsidies for small solar photovoltaic (pv) farms (below 5MW) are also due to end in the spring, following the abolition of subsidies for large solar pv farms in 2015. Subsidies for household renewables are also to be markedly reduced. Community scale renewable energy projects are being hit especially hard with large reductions in payments via the Feed-in Tariff scheme, a sudden end to tax relief for investors in these projects, and the loss of some organisational support. Bio-energy projects have also lost some of their financial support and there is concern about a lack of progress with marine energy and offshore wind energy. Perhaps the most perverse policy change for renewable energy projects is that they will now have to pay the Climate Change Levy, a tax originally set up to penalise carbon emissions. This measure alone, the industry estimates, will add an extra £450m to its costs this financial year, rising to £1bn by 2020/21.[14]

While some reductions to subsidies are justified as the technology costs fall, and there are question marks over the sustainability of certain bio-energy sources, the scale of the cuts has taken many by surprise. Over 1,000 jobs have already been lost in the solar pv sector since the announcements, with thousands more under threat.[15] The most frustrating aspect of these cuts is that they are punishing successful industries. Targets for the deployment of small-scale solar pv, wind, hydro and biogas (via anaerobic digestion) have all been met five years early.[16] Meanwhile, offshore wind farms have been 20% more productive than predicted.[17] But the planned subsidy cuts now mean that the UK may miss its 2020 target for energy generated from renewable sources.[18]

There have also been major cuts to energy conservation programmes, especially those aimed at households. It is no surprise that the Green Deal has been cancelled[19] given its numerous problems, but to do so before alternative proposals have been put together leaves a major gap in efforts to conserve energy. The Energy Company Obligation (ECO) – designed to help those in fuel poverty – has been much more successful than the Green Deal, but a massive 42% cut in its annual funding is now to be implemented from 2017.[20] This is especially irresponsible given the estimate that 7,800 UK deaths per year are as a result of illnesses due to living in cold homes.[21] The government has also abolished zero carbon targets for new homes and buildings.[22]

Even the proposal to phase out the use of unabated coal – the highest carbon fuel – in power stations by 2025 is lacking in credibility. The first problem is that government funding for the development of carbon capture technologies has been cut.[23] Secondly, one of the main replacements for coal is planned to be an expansion of natural gas – with an increasing proportion from shale gas wells in the British countryside.[24] Life-cycle carbon emissions from conventional natural gas are at least nine times greater than renewables, while those from shale gas are even higher – and the latter creates additional risks of local water, land and air contamination.[25]

There are also serious problems with the third strand of the new policy – that of building a new generation of new nuclear power stations. For a start, the national and international nuclear power industry has been experiencing major difficulties since the Fukushima accident, if not before.[26] The current frontrunner for a plant in the UK is the European Pressurised Reactor (EPR). At the time of writing, a final investment decision is due for the Hinkley Point C site in Somerset – but progress elsewhere with this design is not encouraging. One EPR is currently under construction in Finland, one in France and two in China. The one in Finland is nine years late (and counting), costs have nearly trebled and it is at the centre of a legal battle.[27] The one in France is six years late (and counting), costs have more than trebled, and it is under examination by the safety regulator over possible weaknesses in the reactor pressure vessel.[28] The two in China are two years behind schedule[29] – under a significantly less stringent regulatory regime. Estimates of the earliest a new plant could come on stream in the UK have slipped to 2025.[30] Meanwhile, Toshiba – the lead contractor of one of the other consortia planning to build nuclear power stations in the UK – is in severe financial difficulties.[31]

Only plans to continue the expansion of offshore wind offer a serious attempt to tackle carbon emissions from the energy sector.

The skewed priorities can be clearly seen in how subsidies are being targeted. Britain is the only one of the leading G7 economies which is expanding its already large fossil fuel subsidy level.[32] Meanwhile, the subsidies being offered to for new nuclear power stations include very large upfront loan guarantees for construction, 35-year energy price guarantees, and limits on liability for nuclear accidents and long-term radioactive waste management – far more extensive than anything offered to the renewable energy industry. The solar energy industry has pointed out that, for just half of only one of these subsidies (the energy price guarantee) being offered to Hinkley Point C, it could deliver an equivalent amount of electricity (including back-up).[33] Even more could be achieved with cheaper onshore wind.

The situation in the transport sector is also grim. For example, the tax differential between high and low pollution cars has been reduced[34] and large-scale airport expansion is still being proposed.[35]

A complete re-think

The UK had been making steady, if inadequate, progress on reducing carbon emissions – up until the General Election. The backtracking since then has put this progress at risk, not only in terms of tackling climate change, but also by undermining efforts to reduce fuel poverty, create skilled jobs, improve air quality, increase energy security and improve economic performance.

The government needs to prioritise action in three main areas:

- Increase financial and non-financial support for home energy conservation, including a large expansion for the ECO scheme and a replacement for the Green Deal;
- Rapidly phase out subsidies for oil, gas (especially from fracking) and nuclear, and provide appropriate subsidies for renewables, especially wind, solar, marine and associated energy storage technologies, and especially at smaller-scales;
- Scale up efforts to reduce carbon emissions from the transport, agriculture and other neglected sectors.

Extra funding could come from cuts to Britain's huge military equipment budget (see p.7) – justified as climate change is widely acknowledged as a driver of insecurity.

Then the UK would play a leading role in helping the world reach the ultimate goal of "preventing dangerous climate change".

Dr Stuart Parkinson is Executive Director of SGR, and has researched and written widely on climate and energy issues.

References

1 Rudd A, Truss L (2015). Committee on Climate Change's 2015 progress report: Government response. Joint Foreword. www.gov.uk/government/publications/committee-on-climate-changes-2015-progress-report-government-response
2 Dept for Energy and Climate Change (2015). 22 July. www.gov.uk/government/news/controlling-the-cost-of-renewable-energy
3 CCC (2015). Reducing emissions and preparing for climate change: 2015 Progress Report to Parliament. www.theccc.org.uk/publication/reducing-emissions-and-preparing-for-climate-change-2015-progress-report-to-parliament/
4 Office for National Statistics (2015). Energy Trends section 5: electricity. 22 December. www.gov.uk/government/statistics/electricity-section-5-energy-trends
5 DECC (2015). 18 November. www.gov.uk/government/news/new-direction-for-uk-energy-policy
6 BBC News online (2015). 8 December. www.bbc.co.uk/news/science-environment-35044423
7 As note 3.
8 Webber P (2015). SGR Newsletter, no.43. www.sgr.org.uk/resources/uk-household-energy-policy-another-fine-mess
9 Energy Bill Revolution (2014). ECO and the Green Deal. www.energybillrevolution.org/wp-content/uploads/2014/07/ACE-and-EBR-fact-file-2014-06-ECO-and-the-Green-Deal.pdf
10 As note 3.
11 Parkinson S, Mumford P (2014). ResponsibleSci blog, 5 December. www.sgr.org.uk/resources/mind-carbon-gap
12 Woodman B (2015). ResponsibleSci blog, 13 October. www.sgr.org.uk/resources/rudd-s-magic-money-tree-risks-undermining-investments-low-carbon-economy
13 No2NuclearPower (2015). nuClear news, no.80. www.no2nuclearpower.org.uk/nuclearnews/NuClearNewsNo80.pdf
14 The Guardian (2015). 9 July. www.theguardian.com/business/2015/jul/09/green-energy-sector-attacks-budget-climate-change-levy
15 The Independent (2015). 19 October. www.independent.co.uk/news/uk/home-news/hundreds-of-renewable-energy-companies-could-be-forced-out-of-business-due-to-dramatic-subsidy-cuts-a6700466.html
16 DECC (2015). Consultation. 27 August. www.gov.uk/government/uploads/system/uploads/attachment_data/file/469476/Consultation_on_a_Review_of_feed-in_tariff_scheme.pdf
17 Carbon Brief (2015). 13 July. www.carbonbrief.org/qa-has-the-uk-blown-its-green-power-budget
18 The Ecologist (2015). 9 November. www.theecologist.org/News/news_analysis/2986190/leaked_letter_rudd_admits_25_green_energy_undershoot_misled_parliament.html
19 As note 12.
20 Association for the Conservation of Energy (2015). 25 November. www.ukace.org/2015/11/press-release-scandalous-winter-deaths-surge-but-chancellor-slashes-help-for-cold-homes-by-42/
21 Energy Bill Revolution (2015). www.energybillrevolution.org/fuel-poverty/
22 As note 12.
23 The Guardian (2015). 25 November. www.theguardian.com/environment/2015/nov/25/uk-cancels-pioneering-1bn-carbon-capture-and-storage-competition
24 As note 5.
25 Harrison G, Parkinson S (2015). SGR Newsletter, no.43. www.sgr.org.uk/resources/shale-gas-and-fracking-examining-evidence-febmar-2015
26 China Dialogue (2015). 6 November. www.chinadialogue.net/article/show/single/en/8287-Nuclear-on-the-wane-as-grids-adapt-to-renewable-energy
27 The Ecologist (2015). 15 May. www.theecologist.org/News/news_analysis/2859924/finland_cancels_olkiluoto_4_nuclear_reactor_is_the_epr_finished.html
28 The Ecologist (2015). 2 October. www.theecologist.org/News/news_analysis/2985650/flamanville_nuclear_safety_fail_sounds_death_knell_for_hinkley_c.html
29 World Nuclear Industry Status Report (2016). 5 January. www.worldnuclearreport.org/UPDATE1-World-Nuclear-Industry-Status-as-of-1-January-2016-Mind-the-China.html
30 The Guardian (2015). 21 October. www.theguardian.com/environment/2015/oct/21/hinkley-point-reactor-costs-rise-by-2bn-as-deal-confirmed
31 BBC (2015). 21 December. www.bbc.co.uk/news/business-35149520
32 The Guardian (2015). 12 November. www.theguardian.com/environment/2015/nov/12/uk-breaks-pledge-to-become-only-g7-country-increase-fossil-fuel-subsidies
33 Solar Trade Association (2015). 20 October. www.solar-trade.org.uk/solar-could-provide-as-much-power-as-hinkley-point-c-for-half-the-subsidy-cost/
34 Friends of the Earth (2015). July. www.foe.co.uk/sites/default/files/downloads/budget-2015-car-tax-80672.pdf
35 Airports Commission (2015). 1 July. www.gov.uk/government/news/airports-commission-releases-final-report

Messages for the Paris conference: The forgotten dimensions of climate change

Scientists for Global Responsibility Conference and AGM, 31 October 2015 The Gallery, Farringdon, London, UK

Summary by Gwen Harrison and Stuart Parkinson

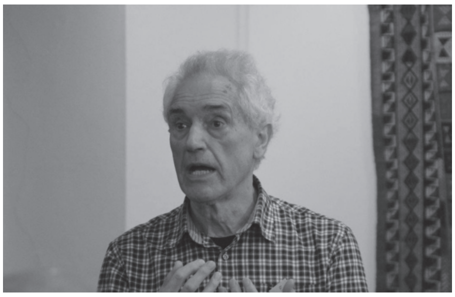
The aim of SGR's 2015 conference was to step back from the main focus of the Paris climate change negotiations – near-term carbon emissions targets and financial transfers from rich to poor nations – to look at some of the broader and deeper issues that are not being discussed. The main areas of discussion at our event were how to keep the overwhelming majority of fossil fuels in the ground, and the links between climate change and the military. About 65 people attended the day.

Keeping 80% of fossil fuels in the ground

The first plenary session began by focusing on key technological options for keeping at least 80% of fossil fuels in the ground, and then on policies and measures that might help achieve this.

Progress towards all-renewable electricity supplies

The first speaker was Prof Keith Barnham, from the Department of Physics, Imperial College, London. He is also author of the book, *The Burning Answer*, which argues in favour of a solar revolution (see review on p.23).



© SGR

Prof Keith Barnham spoke on renewable energy

Keith began by presenting evidence that solar photovoltaic panels (PV) were mainly responsible for bringing the German wholesale electricity price down by 20% between 2007 and 2011, despite only providing 3% of its electrical energy by the end of this period. This, he explained, is because peak demand in Germany matches the peak supply for solar at around noon. He then presented graphs showing that this price fall had continued in the years since 2011. Together with complementary wind energy – which is fairly reliable on a national scale – the expansion of solar could cause the average wholesale price in Germany to fall to zero by 2020. There are distinct similarities with the UK situation, so could we reap similar cost rewards in this country?

To help answer this, Keith introduced the Kombikraftwerk project, which simulated on a small scale how renewables could meet 100% of real-time electricity demand in Germany. The project demonstrated that PV and wind, together, can supply around 78% of German demand. This could be complemented by 17% electricity from biogas, which can be turned up or down as necessary. This system would then require only 5% back-up from electricity storage, contrary to the common claim that renewables require expensive storage systems.

He then presented data showing that the UK has recently achieved similar trends in the growth of PV and onshore wind as Germany did in the early years of its renewable energy growth, and how Britain is ahead of Germany in the growth of offshore wind. If the currently proposed cuts in subsidies are reversed, and the expansion of biogas energy is speeded up, then the wind and PV components of an all-renewable electricity supply are achievable in the UK soon after 2020. Furthermore, the average wholesale price could fall to zero, rather than rise to double the current price, which is the level of subsidy agreed by the government for the planned Hinkley Point C (HPC) nuclear power station. Keith added that the incentives could be paid for through taxation rather than from the current levy on bills, making it fairer for those on a low income, and that all fossil fuel subsidies should be diverted to renewables. Most of this transition, Keith argued, could be achieved by the next election, and then there would be no need for HPC, thus saving the British public a fortune in the longer term!

The 20% solution: look up, wise up, cheer up

The second speaker was Dr Laurence Matthews from Cap and Share UK, and co-author of the book, Framespotting.

Look up: Laurence argued that 'framing' can prevent us from seeing the bigger picture. Climate change discussions are framed in terms of emissions, so we forget to address the root cause: fossil fuels. Using a

© SGR

Dr Laurence Matthews spoke on 'cap and share' proposals

sprinkler analogy, he suggested you can save water by trying to block up the holes (i.e. reducing carbon emissions) or turning the tap off (i.e. not extracting fossil fuels). The latter, he argued, is likely to be more effective than the former. The other key part of the UN climate negotiations involves developing nations pushing for financial assistance to help them reduce emissions and adapt, and wealthy nations being reluctant to pay. Framing everything in terms of 'nations' is a stumbling block.

Both these factors mean the negotiations are making very limited progress. Instead, Laurence suggested a Cap and Share system. The UN would calculate a 'safe' global carbon budget, and would run an auction of extraction permits bid for by fossil fuel companies. The UN would then distribute the money raised equally across the globe to each adult. The cost of fossil fuels would thus increase, but lower users would see a net financial benefit, providing an in-built transfer of money from high to low income groups.

Wise up: Laurence argued that to tackle climate change we need to be politically and psychologically savvy. For example, companies can be persuaded to leave most fossil fuels in the ground by a range of political measures including legislation and consumer pressure (e.g. 'climate safe' labelling, similar to that for 'fair trade', where fossil fuels extracted under the global cap are so labelled).

Cheer up: If we look up and wise up, Laurence suggested that we can cheer up! We must frame strong climate action as the sensible and positive choice, and an insurance policy for the future.

Climate change and military technology

The second plenary session focussed on the ways in which military technologies can change the climate.

Nuclear weapons and climate catastrophe

The third speaker was Dr Philip Webber, Chair of SGR.

Phil began by describing climate modelling carried out in 1983 which indicated that the detonation of 1,000 Hiroshima-sized nuclear warheads would inject enough particles into the upper atmosphere to severely restrict the sunlight reaching ground level, resulting in darkness and rapid, large surface temperature drops.

The research was updated in 2007 and 2014, using the latest climate models. The findings of these studies showed that the 'nuclear winter' would last significantly longer than previously thought putting considerable pressure on global food supplies, and likely triggering a global 'nuclear famine'.

The recent studies also modelled the consequences of a regional conflict (e.g. India-Pakistan) using 100 Hiroshima-sized weapons. (By comparison, a UK Trident submarine's payload is equivalent to about 320 Hiroshima's). In that scenario, 20 million people would be killed by the blast, fires, radiation, etc. Many cities would be abandoned indefinitely. There would also be a decade of cooling in key agricultural areas and severe drought affecting grain harvests.

Hence, Phil argued that the current nuclear arsenals risk massive climate impacts, and he also stressed the serious possibility of accidental launches. We know of numerous close calls during the last few decades, most of which have been averted by human judgement – e.g. people acting against orders. Hacking of warning and launch control systems also presents a more recent, but very real, risk. A former US commander of nuclear forces is calling for the 1,800 US and Russian weapons currently on 'high alert' to be taken off this status to reduce this risk. Phil suggested that we've been lucky to avoid accidental nuclear disaster for 70 years, but asked how much longer our luck would last.

He also outlined a proposal endorsed by over 120 nations, currently under discussion within the UN, for a new treaty to ban nuclear weapons alongside other weapons of mass destruction. Phil suggested this could also be raised in Paris.

Demilitarisation for deep decarbonisation

The final speaker was Tamara Lorincz, International Peace Bureau, who provided a pre-recorded presentation, so she would save the carbon that would have been emitted if she had flown over to the conference from Canada! She discussed the need for demilitarisation to help tackle climate change.

She began by summarising the need for major emissions reduction as demonstrated by UN bodies such as the Intergovernmental Panel on Climate Change (IPCC) and the Deep Decarbonisation Pathways Project. However, decarbonisation plans generally exclude military emissions, despite their being major consumers of fossil fuels. For example, the US Dept. of Defense (DoD) is the country's largest institutional oil consumer. Tamara looked at how military emissions are accounted for in national greenhouse gas inventories (based on IPCC guidelines), and found that reporting remains incomplete and opaque due to confidentiality agreements. Reducing carbon emissions is not a priority for the military. For example, the DoD projects a continued increase in its use of petroleum products over the next two decades.

It is estimated that $1,000 billion per year for 40 years is needed to decarbonise the global economy, and $100bn/y is needed for developing countries to help them adapt to climate change. But the wealthy nations aren't pledging adequate funds. Annual global military spending is currently estimated to total $1,700bn. The US spends $610bn of this – more than all other top 15 military spenders put together – and, furthermore, the Government Accountability Office says it's at high risk of fraud, waste and financial abuse. Despite all this, a formal submission to the UN proposing that military spending be re-allocated to social and environmental priorities was ignored.

In the UK, the military also continues to receive a large budget, buying very expensive weapons systems such as the new F-35 strike aircraft, while spending on tackling climate change is much less.

Tamara stressed the need for disarmament alongside climate change mitigation and adaptation. She pointed to the report, 'Arms to Renewables', which shows how a transition to a greener and more peaceful economy is possible.

During the discussion following the presentation, Phil Webber pointed out that SGR is one of the only organisations to have researched R&D spending on the military compared to that on tackling climate change and other security threats in its *Offensive Insecurity* report.

Poster Sessions

Eight posters were presented at the conference, covering issues such as ocean acidification, communication of climate change, and climate change and war.

SGR's Annual General Meeting

The event also included SGR's AGM. The annual report and accounts were presented, and the National Coordinating Committee elected, with the session concluding with discussion of current and planned activities.

Powerpoint presentations, poster abstracts, photos and other materials from the conference can be downloaded from: www.sgr.org.uk/events/messages-paris-conference-forgotten-dimensions-climate-change

© SGR

About 65 people attended the SGR conference

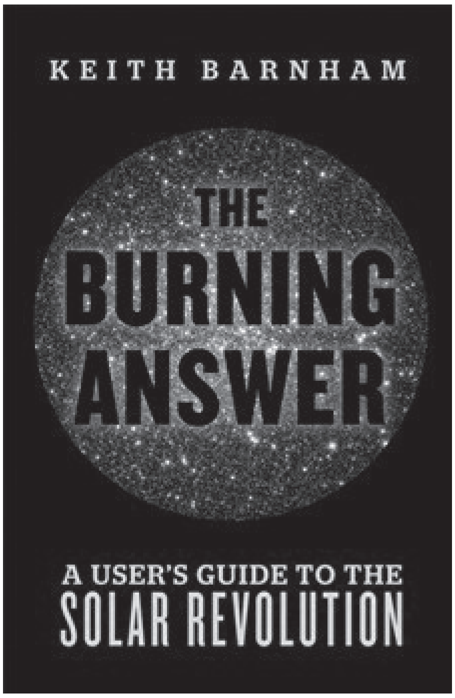
© SGR

The poster session led to some lively discussion

The burning answer: A user's guide to the solar revolution

Keith Barnham, Wiedenfeld and Nicholson, 2015, 320pp., £8.99, ISBN-13: 978-1780225333 (paperback)

Review by Philip Webber



This is an important book. While many of us are aware that society must make a transition to renewable sources of energy as soon as possible, Professor Keith Barnham, SGR sponsor and leading solar cell researcher, explains not only how it could be done, but done quickly. Keith sets out a clear, well-argued, scientific yet accessible, and extensively referenced case for a speedy transition to a completely renewable electricity supply for the UK and suggests various possibilities for electrical or renewable fuel-cell powered transport.

But this is far more than a manifesto for renewables. This book covers an enormous field and is packed with many nuggets and insights that deserve greater publicity and discussion. I refer here to a few.

The first third of this book is a very readable and enlightening explanation of the science that underpins many technologies that feature in our everyday lives, including flat screen TVs, computers, mobile phones and global communications. This is the world of electricity and magnetism, radio and microwaves, light and the miniature devices that manipulate it, capture it and transmit it. Keith introduces this topic with one very straightforward equation: E=hf. This equation calculates the very small amount of energy in each quantum of light/radio wave. Keith contrasts this almost unknown, but very important, equation with the widely known equation $E=mc^2$ which underpins the nuclear bomb and nuclear power.

The contrast between $E=mc^2$ and E=hf is important as it may hold the key to the survival of our species. The choice of government and industry to focus on exploiting $E=mc^2$ has given humans the ability to destroy civilisation and jeopardise life on Earth with nuclear weapons, together with access to a new element, plutonium, which retains its dangerous radioactive state for 300,000 years. But as we live on a planet illuminated daily with immense amounts of heat and light from the Sun, there is an alternative. In the following sections, Keith sets out the immense growth so far of the renewable energy sector – including solar for both electricity and heating, wind, tidal and wave energy, biogas, and geothermal energy – as well as related technologies such as heat pumps and fuel cells. These energy technologies cannot be used to make bombs and there is no long-lasting radioactive waste.

Fortunately, our ability to exploit renewable energy has developed to the point where some solar electricity is now cheaper at peak times than other forms of available power. In an extreme example, in southern Italy, electricity is actually available at zero cost on sunny afternoons. Against much of what we are told in the media, Keith presents evidence from detailed studies using real-life data, that a combination of wind- and solar-sourced electricity, backed-up with a relatively small amount of biogas and storage technologies, could supply 100% renewable electricity for Germany. The same could be done here in the UK – especially as we have *more* wind.

Keith then goes on to explain how the media and some in government have been misled. Some experts have made significant errors. For example, far from claims that around 30% of the UK land mass would be needed to be "covered" by wind turbines or solar panels, only about 1% – roughly the same as the area of existing roofs – would be sufficient to supply current UK electricity demand. The difference arises from two facts: panels and turbines are much more efficient than assumed (this early error has now been corrected) and electricity demand is only about 20% of total energy used. The majority is used for heating and in the form of gasoline products for transport and aviation.

Keith also highlights that the Dept of Energy and Climate Change's 2050 carbon pathways online calculator – which enables any internet user to work out and simulate a low carbon future – has an inherent bias. The model uses energy units (i.e. the total energy use over a year) but does not take account of *power* requirements. This creates a bias in favour of some forms of power generation such as nuclear because the large but continuous power output does not match well with demand – for example, at night. In contrast, peaks in solar and wind power output can often match demand variations – for example, daytime or wintertime peaks. Furthermore, at these peak times, solar or wind power can be the cheapest power on offer so is bought first on the hourly energy market. This pushes down prices for the consumer. Solar and wind power technologies are also capable of being scaled up and installed more rapidly than new nuclear power stations.

There are other fascinating insights: the secret diversion of UK civil plutonium for military use; the UK's role in the global plutonium economy; the benefits and advantages of tidal lagoon power (energy on demand with flood protection); various possible fuel cell options; and the strong government bias for subsidies for fossil fuels and nuclear power over renewables.

In my view, the compelling evidence presented here should be used to inform government energy policy now and for the future. I would hope that the 2015 Paris Agreement will promote longer-term government support for newer renewables such as marine energy, and hopefully the continuation of important levels of support for renewable heat and anaerobic digestion. From my own experience, I am starting to see some of the more established renewable technologies, such as solar, being invested in around the UK even without government finance. This is because the economic case simply stacks up. This is further support for the case made by Keith in this excellent book.

Dr Philip Webber is Chair of SGR.

Scientists for Global Responsibility
Scientists · Architects · Engineers · Technologists

Scientists for Global Responsibility (SGR)
Unit 2.8 • Halton Mill • Mill Lane • Halton • Lancaster • LA2 6ND
Tel: 01524 812073
E-mail: info@sgr.org.uk
Web: http://www.sgr.org.uk

Join SGR - as a Member or an Associate

SGR is an independent UK-based membership organisation promoting ethical science, design and technology. Our work involves research, education, lobbying and providing a support network for ethically-concerned professionals in these areas.

You can join SGR as a member if you are or have been a science/design/technology professional in the broad meaning of the words: our members come from many disciplines including natural sciences, social sciences, engineering, computing, architecture and design, and interdisciplinary areas. They work in research and development, manufacturing, teaching, science writing, or are students or retired. Members are invited to contribute their expertise to help make SGR even more effective.

If you are not a science/design/technology professional, but want to support our work, you can help us by becoming an associate.

Please consider joining by standing order as this will save us time and money, and help us to campaign more effectively.

I would like to become a member/ an associate* of SGR (*delete whichever does not apply)

☐ I enclose a cheque for my annual membership subscription of £_______ (Please make cheques payable to 'Scientists for Global Responsibility') or

☐ I would like to pay my membership subscription by standing order (Fill in the form below)

Annual subscription rates for members and associates:

Waged	**£30.00**
Part/Low Waged	**£15.00**
Unwaged	**£10.00**

Alternatively, you can pay 0.1% of your annual income.

Please send both sections of the completed form to: Scientists for Global Responsibility, Unit 2.8, Halton Mill, Mill Lane, Halton, Lancaster, LA2 6ND.

Thank you

Information provided on this form will only be used to administer your membership. SGR does not pass on or sell information about our members to any third parties.

Title _______ Name ____

Address ____

____ Postcode ____________________

Telephone ______________________ Email ____________________________________

Where did you get this newsletter? ____

Professional qualifications/background # ____

____ (#Associates need not answer this question)

Standing Order Form

To (name of bank) ____

Address (of bank) ____________________________________Postcode____________

Please pay Scientists for Global Responsibility (SGR), Account No. 37174797, at the National Westminster Bank PLC, 501 Silbury Boulevard, Milton Keynes, MK9 3ER (Sort Code 60-14-55) the sum of:

£ (amount in figures) ____

(amount in words) ____

on __ / __ /20__ (date of first payment) and on the same day monthly/ annually* thereafter until further notice.

(*delete whichever does not apply)

Name(s) of account holder(s)____

Account no ____________________________________ Sort code __________________

Signature ____ Date____________

Editorial Issues

The editorial team for this issue of the SGR Newsletter was:

- Stuart Parkinson
- Vanessa Moss

The opinions expressed within, including any advertisements or inserts, do not necessarily represent the views of SGR.

This issue was published in February 2016.

Please send articles, reviews and letters for the newsletter to **newsletter@sgr.org.uk** or the SGR postal address (above).

Copy deadline for next issue: 31 August 2016

Keep in touch between Newsletters

Why not keep in touch between Newsletters by signing up to one of our email lists: Sgrforum (announcements plus discussion) or Sgrupdate (announcements only)?

Alternatively, you may prefer to follow our activities on Facebook, Twitter or LinkedIn.

For further information and joining instructions, please see: **http://www.sgr.org.uk/pages/email-lists**

seacourt naturallyresponsible Printing

This is naturallyresponsible Printing
100% waterless LED | 100% alcohol and substitute free | 100% carbon neutral | 100% renewable energy | 100% recycled FSC stock | 100% VOC free inks
Zero waste to landfill
Printed by seacourt – proud to be counted amongst the top environmental printers in the world www.seacourt.net