GeneWatch UK response to the BIS Consultation, Shaping a UK Strategy for Agri-Tech

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This consultation has reportedly been issued as part of an attempt to justify a significant increase in the amount of taxpayers' money spent on R&D for GM crops in the UK.[1] GeneWatch UK does not agree with this approach. Instead, new mechanisms are needed to ensure that science spending is more publicly accountable and actually addresses the problems being faced by Britain and the world.

The UK Government has adopted an export-led strategy for the economy, which is intended to allow the sale of patented products overseas. However, value-added products currently produced from Britain's farms (such as high quality meat, cheeses and beverages) will be undermined if low-value bulk commodity GM crops are grown in Britain, costs will go up for non-GM farmers (both conventional and organic) due to the costs of segregation and losses of GM-free markets, and Britain's access to agricultural export markets will be damaged. Alternatively, if GM crops are patented here and then sold overseas, this could undermine food security and export markets for some of the world's poorest people.

Priorities for British farming should include increasing home grown horticulture and access to fruit and vegetables for low income families; reducing food waste; and reducing reliance on imported animal feed. Broader engagement is necessary to support farmers, food businesses and consumers and develop the right R&D priorities. Priorities for international research should draw on the extensive consultative process used by the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD).[2]

A strategy which focuses on GM crops will waste taxpayers' money and is unlikely to deliver either new products or economic benefits, as most GM crops fail in trials and never get to market. Currently, British taxpayer-funded research institutions are acting as the PR wing of the large multinational companies which market GM seeds. They are paid not to produce anything useful but to go on the media and claim that they will produce something useful using GM at some point in the future: and that therefore GM regulations must be weakened and retailers must put GM foods back on their shelves. The Government should be aware that this PR strategy is not intended to deliver anything for Britain but simply to open up the European market to Monsanto and other companies. If this happens, British farmers will simply suffer the same problems as US farmers do: they will be locked into a cycle of paying ever more for seeds and associated chemicals as resistance develops to the herbicide-resistant and pest-resistant GM traits which are already on the market overseas.

Background to the current consultation

Government commitments to developing a new "biotech economy" began in the US in the early 1980s and this idea was later copied in the UK and other OECD countries.[3] This idea also became a key plank of the EU's R&D funding strategy. Genetically modified organisms (GMOs) including GM crops, as well as sequencing the human genome, were supposed to lead to a "genomic revolution" in which the life sciences became a new driver for economic growth. Because it was recognised that wealthy economies would no longer be able to compete with cheaper manufacturing costs in countries such as China, the basis of this new economy was produced to be trade in intellectual property, rather than manufactured goods. Funding systems were restructured to allow patenting by universities and public institutes and to expand patenting to treat what previously would have been regarded as discoveries as "inventions". Universities and institutes were encouraged to create spin-out companies and to obtain venture capital investment to get biotech companies to the point where they could be licensed for use by larger firms, or lead to IPOs. This strategy for growth has been

spectacularly unsuccessful with the exception of a few early entrants (in the USA, Monsanto for GM crops and Amgen and Genentech for biotech drugs; in the EU, Novozymes for enzymes) and the research tools market (selling genome sequencing and database tools to researchers largely funded or subsidised by taxpayers).

The restructuring of the research system which was supposed to create a new source of economic growth has instead created a "cycle of hype" in which researchers, funders and investors no longer sell actual products or solutions but instead sell promises that they will provide solutions in the future, provided they receive ever greater taxpayer subsidies and tax breaks (e.g. the R&D tax credit) and other government support. R&D investment decisions are not accountable either to the market (because market rejection is used as an argument for more subsidy, better PR, or weaker regulation) or to the public via democratic processes (because key decisions which influence how taxpayers' money is used to subsidise private decisions are made by a small circle of advisors and wealthy individual investors behind closed doors). Anyone who questions this system or the resulting R&D priorities is seen as a threat to these investments and is often dismissed as "irrational" or "anti-science".

In UK agricultural research the creation of the Biotechnology and Biological Sciences Research Council (BBSRC) in 1994, replacing the Agriculture and Food Research Council (AFRC), was an important commitment to the "biotech economy". The BBSRC and its allies are now fighting to defend the research funding system that they advocated by arguing that more taxpayer subsidy and weaker regulation will allow them to bridge the "valley of death" (i.e. the gap in venture capital funding) and actually get some products to market. An alternative view is that this small circle of advisors has already made a long string of very expensive, bad decisions and it is time for the UK to cut its losses and adopt an alternative approach, leading to wiser R&D investments. This would involve opening up decision-making to take account of a wider range of views, including the views of farmers and the wider public.

The launch of the new Feeding the Future report is a step forward from the long obsession of research funders with GM crops, as it outlines many other areas such as soil science, where research skills have been lost.[4] However, it is unfortunate that the workshops on R&D priorities did not include the wider public, who are important as consumers and also as taxpayers who fund most of the research. Too narrow a range of interests means important issues have been missed, such as how to sustain healthier diets and get more fruit and veg to low income families, and some pet fantasy projects have been endorsed (such as the creation of nitrogen-fixing GM wheat). This same narrow view of consultation means that the report wrongly dismisses the important global International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD), which was much more inclusive. The proposed increased role of the Levy Boards in setting the research agenda will also raise questions for farmers about how well a narrow circle of individuals will represent their interests and improve market access for high-quality British produce in the UK and abroad.

UK researchers' role in the promotion of GM crops needs to be abandoned

The Agricultural Biotechnology Council (ABC), representing the GM crop companies BASF, Bayer, Dow, Monsanto, Pioneer (DuPont) and Syngenta, continues to seek to expand the GM crop market around the world, despite opposition from many consumers and farmers. In June, the ABC met ministers to agree plans to[5]:

- Spend more taxpayers' money on R&D for GM crops and on "education";
- Promote GM crops in developing countries;
- Remove regulatory and political barriers.

Academics from UK universities, such as Reading and Edinburgh, and research institutes, such as Rothamsted Research and the John Innes Centre, were also present, along with representatives of the National Farmers Union (NFU). The main role seen for publicly-funded researchers is to counter criticism from anti-GM groups as well as to promote pro-GM education including in schools. This is essentially a PR role, funded by British taxpayers. It is unlikely to change public opinion or to deliver anything of value. The ABC report of the meeting admits that GM crops are not suited to British farming, referring to: "*The structure of agriculture, which is made up of a large number of small farms looking at different sectors, which makes commercialisation difficult*". It also refers to difficulties with "*regulatory barriers and political divisions at national and EU level*", an implicit reference to bans on GM crops in six EU countries and opposition to GM from the Scottish Government and Welsh Assembly Government.

UK researchers are also expected to build "*better on the ground presence in Africa, perhaps by working with universities*", although the promotion of GM crops in Africa is likely to be controversial and could undermine food security and export markets for some of the world's poorest people.

The ABC's PR strategy is based on getting academic scientists to promote promises of future GM crops, which provide magical solutions to complex problems, as a distraction from the actual problems experienced by farmers already growing GM crops in the USA and elsewhere. The lack of a market for such crops (except at reduced prices for feed or biofuels) is also ignored. In a letter to the Food Standards Agency in 2009, the ABC stated, "*It is important that when consumers are thinking about GM, they are considering the future as much as the present*." The aim is to open up markets in Europe and developing countries to GM crops before farmers realise the problems. It is hard to see how this is in the interest of either farmers or consumers.

GM crops now and in the future

To date there have been 26,568 field trials of GM crops in the USA, of which 11,025 have been for herbicide-tolerance or insect-resistance traits (the main traits currently on the commercial market).[6] The pipeline for crops awaiting approval in the EU for import or cultivation consists overwhelmingly of herbicide-tolerance, insect-resistance or stacked traits, produced by the major multinational seed companies.[7]

GM crops were developed for use in large-scale monocultures in the USA. The monopoly control of a small number of companies, such as Monsanto, over seed, using controversial GM patents, has trapped farmers in North and South America into a system in which they are paying for continual seed price hikes while company profits boom.[8] At the same time, farmers are using more weedkillers to tackle superweeds, which have grown resistant to the herbicides used with GM herbicide-tolerant crops, especially Monsanto's RoundUp, and some famers in the USA are now warning European farmers not to make the same mistakes they did.[9] Pests are also becoming resistant to GM maize and cotton pest-resistant crops.[10]

There are major concerns that poor farmers in developing countries will become trapped in a cycle of poverty, unable to pay for seed price hikes and expensive chemicals if they grow GM crops (including the increasing costs and risks as resistance develops in weeds and pests). Serious problems have already occurred with GM cotton in India and a Technical Committee reporting to India's Supreme Court has recently recommended a ten year moratorium on field trials of many GM crops, leading to continued intense debate in this controversial area.[11] GM crops remain controversial in many other countries, for example both China and India have moratoriums on growing GM food crops (although both countries produce GM cotton) and Russia and Kenya have bans on GM imports.

Controversy also remains about potential unintended effects of GM foods on human health, and the difficulties in assessing such effects using short term animal feeding studies. There are five main areas of food safety concern:

- The genetic modification itself may make the plant toxic when eaten, or alter its nutrient content in ways that may be harmful.
- The weedkillers used with herbicide-tolerant GM crops may be harmful to people eating the crops or living in the area when the crops are sprayed.
- The new GM characteristic may cause allergies.
- If antibiotic resistance genes are used, they may increase problems with drug resistant diseases.
- The GM process may have unintended effects on the plant, which may affect food safety.

It is unlikely that these issues will ever be fully resolved since certainty is unachievable and new genetic modifications can always introduce new risks. GM crops create a fundamental shift in control over the food chain because consumers are unable to tell by looking at a food what traits it may have been modified to contain and are thus dependent on the regulatory system, which they may not trust.

Whilst enthusiasts for GM crops advocate an end to segregation and labelling, such measures remain an important part of risk management (allowing recalls if anything goes wrong) and are essential to allow consumer choice. This means that in practice there will be costs to conventional and organic farmers of introducing GM crops, associated with segregation and cleaning of processing equipment and loss of markets due to GM contamination incidents. [12,13,14,15,16]

An agri-tech strategy: what priorities for Britain's food supply?

Total consumer expenditure on food and drink in the UK was £179 billion in 2011. Overall at least 15% of edible food and drink purchases are wasted each year: avoidable food and drink waste in the home is estimated at £12 billion, with bread the most wasted food, followed by vegetables and potatoes. Twenty five countries accounted for 90% of UK food supply in 2011, and food was also imported from many other countries, indicating a high diversity of supply.[17] The UK supplied slightly over half its own requirements (51.8%) but only 23% of its own fruit and vegetable supply: this is the food group in which the UK has the largest trade deficit. Food price rises had a strong effect on food shopping for low income households in 2011, with many cutting back on fruit and vegetables. This is of particular concern because low income diets are lowest in fruit and veg and highest in sugars and such diets are expected to increase expensive healthcare costs. Imports (net trade) in food and drink are also a major contributor to carbon dioxide emissions and global resource use. Although air freight of food accounts for only 1% of food tonne kilometres, it produces 12% of the UK's food transport carbon dioxide emissions.

These figures suggest that the UK needs to produce more (and waste less) home grown fruit and vegetables and ensure these reach low income families. The trade-offs between environmental and social impacts in different countries and economics, distribution and affordability are complex, but there is clear potential to benefit health and food security and reduce environmental impacts from air freight and waste.

There is also widespread agreement that the EU as a whole needs to reduce its reliance on imported animal feed, and that the poor economic viability of many UK farms needs to be improved.

Some important questions are:

- What policies and R&D would be good for horticulture in Britain?

- What policies and R&D would be help reduce dependence on imported animal feed and other inputs?
- What policies and R&D would help consumers (especially poorer consumers) and farmers?

Some relevant issues are considered below, but the most important lesson is that a broad range of people need to be engaged in developing the R&D agenda if it is to address the wide range of problems that we face.

Reducing reliance on imported animal feed

Although the Royal Society continues its obsession with Malthus, the evidence that global hunger and under-nutrition is largely a problem of production (rather than poverty) is weak and strongly disputed. However, it is widely accepted that grain supplies are increasingly being squeezed (and prices increased) by increased demand for grain-fed meat and diversion of supply to biofuels production. Europe has become dependent on imported grain for animal feed, much of which is GM soya and maize. Globally, there are major increases in corn, soya and wheat prices, leading to financial pressures on British farmers especially in the pig and poultry sectors.[18]

However, the idea that this problem can be solved by growing GM feed in Europe or importing yet more GM feed is misguided as a quick glance at the US shows. This year's poor GM maize crop (and diversion into biofuels) has led to a feed crisis in the US in which hungry cattle are now being fed sweets and ice-cream sprinkles, which are cheaper than buying feed.[19] US farmers are also searching for alternative feed for pigs.[20]

Grain-fed meat production is significantly more resource intensive and damaging to the environment than pasture-fed meat production, so an emphasis on expanding GM maize and soya production for animal feed neglects important alternative steps that could be taken to make the production of meat and dairy products more sustainable. Grain-fed meat is also much less healthy than pasture-fed meat or game in its fatty acid content.[21,22,23].

There is no quick fix to this problem but changing farming practices and returning to more grazing is an important part of what is needed.[24]

Supporting farmers and consumers

The industrial food system has tended to shift production and distribution towards 'long-food chains' rather than 'short-food chains' (based on sourcing the cheapest, rather than the freshest or highest quality, ingredients); to create mass-produced, standardised products, often high in salt, sugar and unhealthy fats; and to squeeze farm-gate prices. Whilst there have undoubtedly been some benefits in terms of ensuring food supplies in relatively wealthy countries, there have also been many widely recognised downsides, including negative environmental impacts (e.g. depletion of soils and water resources, loss of biodiversity, unsustainable use of fossil fuels and agricultural inputs); the persistence of global hunger at the same time as a global epidemic of obesity; the exacerbation of health inequalities and rural poverty; and the disconnection of the public from farming and the food supply.

These problems will not be solved by considering agriculture in isolation or by focusing on purely technical approaches. The Government's localism agenda opens up considerable opportunities to support and encourage Local Food Systems and to link health, environmental and economic benefits at a local level.[25] Whilst 'short-food chains' clearly cannot supply all the products consumers may wish to buy, some of which are dependent on fairer international trade (e.g. oranges, bananas, tea, coffee), they can reconnect consumers with a wide variety of local products (meat, dairy, vegetables, fruit) and at the same time tackle many of these issues of sustainability and access to healthy diets in the context of

locally produced seasonal food. Closer consumer-producer links allow people to learn more about, and even become directly involved in, the process of food production and supply. Thus opportunities for education (in its broadest sense) also open up, together with an improved relationship between farmers and consumers.

The Technology Strategy Board (TSB) has recently begun to recognise the need to facilitate more SME-led innovation that is not focused on biotech laboratories but can implement ideas of practical area of relevance to farming and food and drink, across the whole supply chain.[26] This type of approach could open up opportunities for UK businesses to develop technologies and innovative systems that can improve the competitive position of the agriculture and food sectors and deliver tangible economic benefits to the broader economy. Current science and innovation policies tend to undermine Local Food Systems - by diverting resources and by adding costs (e.g. the costs of segregating GM crops, which would fall on conventional and organic farmers) - rather than supporting them. In contrast, more focus on agronomy (including agro-ecological methods) can be a means to incorporate and enhance farmers' knowledge of natural resources, as a basis for them to gain from the value that they add.[27]

A recent report by the HGCA found that no single agronomic factor has had a clear dominant influence on trends in UK wheat or oilseed rape yields over the last 30 years. Plant breeding has continued to deliver genetic improvement in both crops, but until recently uptake of higher-yielding oilseed rape varieties on farm was relatively poor, with farmers prioritising other traits. Some agronomic practices have also been driven by prices or policies, with growers seeking to maximise profit rather than yield. The report concludes that to restore rising yields in the face of warmer conditions, potentially more extreme weather, economic or environmental pressures and evolving weed, pest or disease threats, there is a need for some changes to farming systems, with a longer-term and more holistic approach to agronomy.[28] These issues have been neglected since the reorganisation of R&D to prioritise biotech research in labs and abandon Agricultural Colleges and extension services (outside Scotland).

In contrast, Scottish Government policy has explicitly targeted effective integration of R&D spend to benefit both government and producers.[29] Scotland's Rural College[30] has an active non-GM research programme on malting barley, using genetic and other information to improve crop quality, nitrogen use efficiency, disease resistance and crop resilience in the face of climatic change. The role of crop diversity and plant traits in nitrogen capture are also being explored.

More radical approaches would break down disciplinary boundaries and involve farmers and others more directly in research. [31]

An agri-tech strategy: what priorities for exports and the global food supply?
According to Defra figures, in 2011, there were £18.1bn of UK food chain exports of which £10.3bn were highly processed, £6.2bn lightly processed and £1.6bn unprocessed. The value of imports is greater than the value of exports in each of the broad categories of food, feed and drink in the UK except 'Drink' which had a trade surplus of £1.82 billion in 2011, largely due to exports of Scottish Whisky. Drinks are the largest export category by far with a total export value of £6.8 billion in 2011, an increase of 25% on 2009 at 2011 prices. Much of the increase was to existing markets; USA, France and Singapore plus emerging markets such as Brazil and Mexico. Cereals is the next largest export group with an export value of £2.0 billion followed by the meat and fish categories at £1.7 and £1.5 billion respectively. Export values in 2011 increased with whisky, wine, cheese, poultry meat, beef and veal, lamb and mutton, milk and cream, bacon and ham and butter all rising by over 10%. In 2010, around 5,000 traders were recorded as exporting food, feed and drink to the EU and around 4,000 exporting outside the EU: most were small and medium-sized enterprises (SMEs).

The National Farmers Union Scotland argues that the export success if products such as Scottish Salmon, beef and whisky could provide Scotland's dairy industry with a "piggy back" into emerging and international markets and Scotland's dairy producer First Milk is now targeting the Chinese market with help from the Scottish Government.[32] In comparison, Defra has been slow to identify export opportunities for businesses in the rest of the UK.

The Defra figures also show that world population is currently growing 1.1% per year and increased 30% between 1990 and 2010. Food production has grown at a faster rate, currently 1.6% per year, and was 56% higher in 2010 than in 1990. Domestic food prices in developing countries remain about 25% higher relative to non-food consumer prices than in early 2005, with particular impacts on the urban poor who often spend more than half their income on food.

Changing agricultural practices and land use can have significant impacts on the social and economic circumstances of farmers and consumers, particularly in developing countries.[33] The Royal Society's promotion of the concept of "sustainable intensification"[34] glosses over many of these issues by taking a utilitarian approach in which scientific institutions (such as the Royal Society itself) are capable of weighing up and making decisions about what is best for farmers and consumers then somehow promoting these solutions worldwide. This contrasts with a rights-based approach to considering the ethical implications of sustainable intensification, and with 'bottom-up' approaches to decision-making, which may lead to very different decisions.[35, 36,37] This is one of the weaknesses of the Foresight report on Food and Farming Futures[38], which makes a blanket global statement about restricting the expansion of agriculture onto new land, without considering highly variable local circumstances and the politics and economics of how decisions will be made about land use in practice on the ground.

It is therefore a matter of serious concern that the 'Feeding the Future' report continues to dismiss the IAASTD, which adopted an inclusive approach to developing global research and development priorities for agriculture, and to position the UK and the Royal Society in opposition to this approach.

There is a danger that the concept of "sustainable intensification" as promoted by the Royal Society and others presumes that Britain, working with the big global agriculture multinationals, will decide land use priorities for the whole world, and economic priorities for vast swathes of the global population, many of whom remain dependent on agriculture for their livelihoods. In many countries, biotechnology departments act as advocates of this transformation, in the name of science, whilst other departments and civil society actors, including small-scale farmers, often remain opposed. Since it is barely credible to claim that the British economy will gain significantly, or that British companies play anything but a minor role in this proposed transformation, it is hard to see anything but downsides to British research institutions promoting GM crops in Africa, including economic risks due to wasting public money; and reputational risks due to being associated with taking what many will argue is the wrong side in a major battle. This could damage export markets for other British products which actually exist (such as cereals or seed potatoes[39,40]) or are more likely to deliver on their promises.

The global value of genetically modified (GM) seed was valued by the industry at USD 13 billion in 2011[41] (although this is likely to be something of an exaggeration), with the main markets in the US and South America. However, the total commercial world seed market was mostly non-GM, worth approx. USD 45 billion.[42] Seed saving and sharing also remains important in many countries, including in Europe.

Problems with the BBSRC's R&D strategy

The BBSRC continues to fund GM crop research, mainly via Rothamsted and the John Innes Centre. Much of this research is disconnected from reality, such as the plans to develop nitrogen-fixing wheat. Other research uses GM techniques in the laboratory to help identify the genes for useful traits, but is more likely to deliver improved crop varieties through genetically-informed conventional breeding strategies (such as marker-assisted selection, MAS) than through using GM. In China, researchers are turning to marker-assisted selection (using genetic markers identified using arrays to speed up conventional breeding) for maize[43] and livestock[44]: useful complex traits can often be developed more quickly this way without resorting to genetic modification. Whilst breeding new varieties will remain important, the BBSRC has also neglected many areas of research (such as agronomy and soils) which are critical to meeting farmers' needs and supporting food production.

Nutrient-altered GM crops

The John Innes Centre's purple tomato is an example of this bad idea (funded by the BBSRC and the EU FP6 and FP7 research programmes). The tomato is engineered to contain enhanced levels of antioxidant anthocyanins and JIC has made highly dubious claims of health benefit based on a single study in a strain of cancer-susceptible 'knock out' mice.[45,46] In on-line commentaries, Dr Andrew Wadge, Chief scientist at the Food Standards Agency, the NHS, and Cancer Research UK all pointed out that the evidence for any possible anti-cancer effects of anthocyanins in humans is very limited.[47,48,49] The role of antioxidants in health is now very controversial and large-scale clinical trials with supplements have suggested some are harmful.[50] Regulating this area will be a minefield and there is no shortage of existing healthy fruit and veg, which people will prefer to eat and which will be more affordable.

Nitrogen-fixing GM wheat

Nitrogen-fixing GM crops were first promised more than 30 years ago (in the US Office of Technology Assessment (OTA) report, published in 1981). This research is still considered "high-risk" (i.e. unlikely to deliver) and long-term (i.e. requiring several more decades) even by enthusiasts such as the Royal Society. GM nitrogen fixing may prove impossible because it involves making two organisms (a crop plant and the nitrogen fixing bacterium) to work symbiotically by genetically modifying both.[51]

Other GM wheat applications

Researchers at the JIC have contributed significantly to understanding the stability of the wheat genome and barriers to cross-breeding. However, greater understanding obtained through genomic information and identifying genes in the lab is more likely to deliver complex traits and improved crop diversity through improved breeding strategies than GM. So far no GM wheat has progressed to commercial approval despite many trials worldwide. Current trials with GM wheat intended to repel aphids are also at an early stage and the likelihood that aphids become habituated to the repellent is high. There remains strong public opposition to introducing GM wheat into the food chain.[52]

GM potatoes

Nematode-resistant and blight-resistant GM potatoes have been grown in field trials in the UK. There is no sign that either product is close to market and there are alternative non-GM varieties that show good blight resistance. Nematodes are best controlled by ensuring seed potatoes are produced in land free of nematodes and, where nematodes are found, to place restrictions on the use of the land and the disposal of crops, waste and soil to prevent the pest spreading.

GM insects

The Oxford university spin-out company Oxitec is developing GM agricultural pests and has received more than £1.5million in grants from the BBSRC. The GM pests are intended to mate with wild GM insects and the female offspring die at the larval stage, which is intended to crash the wild population. However, results of experiments with the company's GM mosquitoes have so far been poor and Oxitec has been unable to explain how it will deal with the large number of dead GM caterpillars expected in food crops, the difficulties of preventing the spread of releases to environmentally sensitive areas, or with the complexities of predicting the impacts on ecosystems.[53]

Due diligence for R&D investments: who is responsible?

Enormous sums of public money are being wasted because there is no incentive for anyone to conduct due diligence, particularly what might be called "scientific diligence", on patented products such as GMOs. It is routinely assumed that public sector researchers working in partnership with the private sector, overseen by funders such as the BBSRC, will invest public money wisely. However such R&D projects are not accountable to the market or to taxpayers. Neither the scientists who work on them, nor their private sector partners, nor the research councils that spend taxpayers' money, carry any risk (apart from the risk that public funding will be cut). As a result, research funding decisions are highly vulnerable to vested interests making unsubstantiated claims about what will be delivered. Indeed, hype is now regarded as essential by researchers in order to get funding, by public sector funders to defend their decisions, and by private-sector investors in order to secure exit strategies for their investments.

Whilst ministers are anxious not to intervene to "pick winners", there is a danger that the current system specialises in picking losers that do little more than sucking money from the Treasury and selling misleading promises to politicians and the public in the press.

There is no simple answer to this problem as the outcomes of research (particularly "blue skies" research) are by definition uncertain. However, steps must be taken to try to waste less money, reduce opportunity costs and broaden skills and research areas. A one-off assessment of the costs and benefits of highly uncertain future technologies is unlikely to help, but broader scrutiny and inputs to decision-making and on-going appraisals and analysis, combined with a greater awareness of the assumptions on which claims of progress have been based, would reduce the risk of throwing 'good money after bad'.

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