ENVIRONMENT

CLIMATE CHANGE HAVE WE LOST THE BATTLE?

Institution of MECHANICAL ENGINEERS

Improving the world through engineering

EVEN WITH OUR BEST INTENTIONS, THE UK WILL NOT REACH ITS 2050 EMISSION TARGET UNTIL 2100 OR BEYOND UNLESS WE RADICALLY RETHINK THE WAY IN WHICH WE APPROACH CLIMATE CHANGE POLICY.

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With only four decades to go, the UK is already losing the climate change mitigation battle. The greenhouse gas emission targets set by the Government require a rate of reduction that has never been achieved by even the most progressive nations in the world. If the UK is realistically going to reach an outcome equivalent to a reduction of 80% by 2050, we need to start mapping out an alternative solution using all engineering methods possible and not only relying on mitigation.

This report has been produced in the context of the Institution's strategic themes of Energy, Environment, Education and Transport and its vision of 'Improving the world through engineering'.

Published November 2009.

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COP15 OR COP-OUT?

In December 2009 the nations of the world will converge on Copenhagen, Denmark, and try to agree a replacement to the Kyoto Protocol. The current outlook for a forward thinking, legally binding global agreement is not looking good. Nations will inevitably be swayed by domestic economic, social and political concerns. Furthermore, with the world focused on trying to pull out of what is considered the worst recession in sixty years, the green agenda will undoubtedly take a back seat for the next few years.

In the UK, the current administration has attempted to address the challenges of climate change by passing the Climate Change Act (2008). It has introduced a wide range of targets and carbon reduction budgets to reduce our emissions of greenhouse gases (GHG) to 80% below 1990 levels by 2050. Furthermore, it has created an intermediate target of a 34% reduction by 2020. The Institution of Mechanical Engineers applauds these first steps in tackling one of the most important challenges mankind will face over the next few centuries.

However, although some practical actions have begun, the current Act and the associated policies the UK is putting in place to deal with climate change will not come near to achieving the 80% reduction target by 2050.

Furthermore, the Act has no real penalty for failure, and the current Government will be but a distant memory by 2050. Therefore, the question has to be, are the policies being adopted simply a cop-out so that the UK does not have to take decisive and serious actions, many of which may be unpalatable to politicians and the general public?

If this is correct, have we therefore already lost the climate change mitigation battle?

THE CALL TO ACTION

To decarbonise the nation and achieve the 80% reduction in GHG output by 2050, the UK will need to undertake a monumental task at a scale it has never seen before. Using work undertaken by Professor Roger Pielke of the University of Colorado, the UK would need to reduce carbon output per unit of GDP by over 5% annually until 2050. Between 2001 and 2006, we achieved an average of 1.3% annual reduction. A progress report from the Committee on Climate Change finds decarbonisation of the UK economy in more recent years to be ‘very limited’.

On a global perspective, the UK is one of the better performing nations – China, United States and Germany all having economies with higher carbon intensities. France has the most decarbonised economy among the large developed nations. This was achieved as it moved towards nuclear power as the predominant source of electricity generation. However, today France is struggling to increase its decarbonisation rates.

For the UK to be on track to achieve the emission reductions required by the Act, it would have to become as carbon efficient as France by about 2015. To put the magnitude of this challenge into perspective, it is equivalent to the UK constructing and putting into service about 30 new nuclear power stations in the next five years, while retiring an equal amount of coal-fired generation!

WINNING THE CLIMATE CHANGE WAR

With the climate change policy direction of the current Government being primarily focused on mitigation, the UK is unlikely to achieve the 80% reduction in GHG emissions by 2050 unless unprecedented levels of public investment are directed towards this task.

The Institution of Mechanical Engineers believes that a realistic date to achieve the 2050 targets, based on current policy, is 2100 at the earliest – some 50 years later than targeted. By this time, climatic changes in the world will create social, economic, and environmental tensions which could spark regional conflict and possible loss of life.

Although the above scenario is of concern, the Institution firmly believes that it is not too late to reassess our future course and implement a climate change battle plan which can help protect our society, offset CO_2 emissions and give the additional time for mitigation policies to take hold. This we call the MAG approach.

MAG APPROACH TO CLIMATE CHANGE

MAG is the integration of Mitigation, Adaptation and Geo-engineering into one unified and coherent policy which addresses both national and international concerns.

Mitigation is the on-going reduction of GHG emissions from all sectors of society, such as energy production, transportation, the built environment and so on. It will remain the centrepiece of any climate change policy.

Adaptation is ensuring we adapt and protect our critical assets such as power stations, transport links and population centres from flooding, overheating and sea level rises. In some extreme cases, this would mean planned abandonment of settlements and existing infrastructure.

Geo-engineering is using technology to try to slow the global temperature rise by either removing carbon dioxide (CO_2) directly from the atmosphere or reflecting solar radiation back into space.

This MAG approach to climate change would allow the UK to achieve an outcome equivalent to meeting the 80% target (very possibly by the 2050 target date); while simultaneously transitioning to a low-carbon economy at a realistically achievable rate, and adapting to climate change impacts which are already inevitable as a result of damage done to the atmosphere to date.

The geo-engineering technologies would be gradually reduced over time as mitigation policy takes affect. Alternatively, the CO_2 removal technologies could be maintained for a longer than needed period to reduce historic CO_2 already in the atmosphere.

LEADING THE CHARGE

It is the Institution's view that the MAG approach would be better managed by remodelling the Department of Energy and Climate Change, giving it significant powers to implement what is necessary and needed in the war against climate change. This new Department of Energy and Climate Security (**DECS**) would have the additional responsibility of ensuring energy security – both in international supplies and intermittency of supply (especially from renewable energy generation).

Furthermore, the Institution believes that the MAG approach will only be effective if DECS merges all actions into one definitive national battle plan that spans at least 100 years. The Institution's unified MAG strategy allows realistic mitigation targets to be set, planned adaptation policies to be put into place (thus helping industry estimate pre-planned future activity) and geo-engineering research, development, deployment and eventually decommissioning to be mapped out.

DECS biggest challenge will be in organising and directing the nation's resources and skills in the war on climate change (Mitigation or 'rationing' of resources and emissions, Adaptation or 'defence' of our assets, and Geo-engineering or 'attacking' CO_2 concentrations). This will be a monumental task for the UK to undertake, even eclipsing the efforts and resourcing deployed during the cold war.

KEY RECOMMENDATIONS

The Institution of Mechanical Engineers urges Government and other stakeholders to consider the following three recommendations to ensure the UK is best prepared for the future global climate change challenges:

1. **Adopt a MAG approach to climate change policy to help reach our targets**. The UK will fail to achieve the outcome desired by the 2050 80% GHG reduction target without the adoption of a unified **MAG policy**. This single integrated policy approach would continue mitigation policy (such as decarbonising energy and transport systems) as well as develop effective temporary geo-engineering solutions and an adaptation strategy to protect critical assets from inevitable climate change impacts. This approach would be a world first and offer a possible global route-map for many other nations. The full adoption of a MAG policy could also increase the UK green sector to over **2 million jobs by 2050**, guaranteeing many organisations decades of work reducing emissions and protecting our nation.
2. **Introduce centralised control for climate change policy**. All parts of Government responsible for mitigation, adaptation and geo-engineering activity should be moved into a remodelled Department of Energy and Climate Change (DECC). This new 'security' department (**Department of Energy and Climate Security – DECS**) would have sole responsibility, and the necessary powers, to direct national funding, planning, development, commissioning and implementation of the MAG strategy, having priority above nearly all other departments.
3. **Develop a comprehensive MAG battle plan to secure our future and help industry plan future skill requirements**. The Government should work with the engineering profession and business community to develop a comprehensive plan for the implementation of geo-engineering and adaptation alongside the transition to a low-carbon economy. This plan should be scaled over at least 100 years or until the geo-engineering element is eliminated.

DECS BIGGEST CHALLENGE WILL BE DIRECTING THE NATION'S RESOURCES AND SKILLS IN THE WAR ON CLIMATE CHANGE.

CLIMATE CHANGE ACT: AN ACT OF FAITH?

On 26 November 2008 the British Government enacted the Climate Change Act. This groundbreaking piece of legislation mandated reductions in national greenhouse gas emissions and committed the UK to so-called legally binding targets and rolling five-year carbon budgets[1]. As the first legislative instrument of its type anywhere in the world, the Act seeks to communicate to the global community the UK Government's determination to lead the world in the transition to a low carbon future.

The Act requires Government to set out its targets and budgets within defined timescales, the emissions target being set at an 80% reduction in national greenhouse gas emissions by 2050, relative to 1990 levels. Furthermore, as an interim step, a series of ambitious carbon budgets have been established to achieve a 34% cut by 2020[2]. Both the Act and the carbon budgets have far reaching implications for the UK's economy, industries and citizens and are currently unique in an international context. The Government believes that the level of emissions reduction it has mandated is achievable at a cost of between 1–2% of GDP in 2050[3].

These adopted targets now underpin Government policy in the area of climate change mitigation, most recently demonstrated with the launch of a suite of Government Low Carbon Transition Plans[4,5,6,7] in July 2009. These plans lay out specific emissions targets and objectives for the full range of Government departments. The practical actions, investments and changes needed for delivery will, however, largely fall outside of direct Government control.

The targets and budgets created will form the basis of the UK's negotiating position at the United Nation Conference on Climate Change (COP15) in Copenhagen in December 2009[8]. However, is this a long-term gamble, or act of faith, which already looks unachievable?

THE SIGNIFICANCE OF COP15

In December 2009, the next UN Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP15) will be held in Copenhagen, Denmark.

The primary objective of COP15 is to establish an ambitious agreement on reducing greenhouse gas emissions from 2012 – a post Kyoto Protocal agreement. Indeed, if a new agreement is to come into force before Kyoto expires, COP15 is the final opportunity to do so.

CONTRACT AND CONVERGE

The Government's targets and budgets have been set using a top-down approach based on the principle of **contraction** and **convergence**. This approach involves emissions from industrialised nations reducing (contracting). At the same time, emissions from all nations converge to an overall target consistent with stabilising greenhouse gas concentrations within the atmosphere at an acceptable level. In this way, over time emissions will contract and converge to an equal share per person globally, regardless of the nation in which they live. The desire from most authorities is to constrain the global mean temperature rise to 2°C or below. This translates the contraction and convergence requirement to an 80% reduction target for the UK relative to 1990 levels by 2050 and the adopted budget profile through to 2020.

The Institution of Mechanical Engineers supports the principle of contraction and convergence. However as a body representing the profession largely charged with delivery of the technology and infrastructure required to meet the challenge, we ask whether these targets and budgets are achievable in any real sense? And if not, what are the implications for the UK and the wider global community?

Many in the policy-thinking community are beginning to regard the UK's climate policy as an act of faith. The Institution therefore has to ask if there are adjustments that could be made to current policies to improve the prospects for a successful outcome? Or, is there an alternative approach that can build on what we already have?

These questions are particularly relevant in the context of the Government's consistent inability to meet its green targets. In this regard, recent reports[12] concluded that over half of the 138 high level green targets set since 1997 are likely to be missed and that in the area of climate change two thirds have failed or are unlikely to be achieved.

To seek some answers to the questions posed, the Institution of Mechanical Engineers undertook an examination of the UK's potential to meet these targets and an assessment of the associated engineering challenge. In the process of undertaking the work, leading international experts in policy development and thinking were consulted along with senior members of the Institution working in key industrial positions. In this report the Institution brings this work on economics, policy analysis and engineering feasibility together to present an engineer's view of a more robust approach to climate change policy.

ENGINEERING THE TRANSITION – THE SCALE OF THE CHALLENGE

The Institution of Mechanical Engineers has conducted an analysis on the scale of engineering work needed to meet the targets and budgets of the Climate Change Act. The Institution's **UK 2050 Energy Plan**[13], prepared as part of the International Future Climate Project[14], proposed a scenario in which the 2050 target is met using known technology and demand reduction. The Institution's members concluded that, even with a dramatically reduced demand level, the scale of the engineering task required would still be without historical precedence.

In the Institution's scenario, decarbonisation will be achieved by changing all electricity generation over to low-carbon or zero-carbon sources and converting transport largely to electric vehicles, thereby reducing overall power sector and transport sector emissions. For energy production, the UK would switch primary energy supply from fossil fuel to low carbon or renewable sources (oil and gas use is cut 90% by 2050 and coal use is more than halved) and develop and use carbon capture and storage (CCS) for all large scale fossil fuel power generation and fossil fuel intensive process plants eg. steel and cement.

To put this task of decarbonising UK primary energy supply into an engineering perspective, the plan calls for:

- the delivery of 16 nuclear power stations equivalent in size to the existing Sizewell plant by 2030 and an additional four by 2050 (current UK plans are for only nine new stations)
- a massive expansion of wind energy generation with a total of around 27,000 turbines operational by 2030 and a further 13,000 coming on stream by 2050 (currently the UK has 2,600 turbines in operation)
- numerous additional facilities to be built across the nation for the extraction of energy from biomass, solar, waste, tidal, wave and hydro sources.

In addition to the provision of these significant pieces of energy supply kit, major investment and development will be required to improve the electricity distribution grid, set up local heating networks, deliver electricity storage capacity to cope with greater intermittency of renewable sources, and make grid connections to other EU countries.

TIME TO BUILD

To give some sense of the timescales associated with the delivery of the individual tasks in the shopping list of engineering projects presented in the plan:

- the recently announced electrification of the main railway line between London and Bristol/Swansea will take eight years;
- Network Rail's plan for a high speed link between London and Scotland envisages a 20 year implementation task;
- timescales for power station projects can often reach five to ten years. For example, the third reactor currently being built at Olkiluoto in Finland, which is Europe's first new nuclear plant for 30 years, is likely to take more than seven years to build.

Beyond the magnitude and timescale of the task, any move towards global decarbonisation will encounter several additional key barriers, such as:

- the technologies required to deliver the plan are known but many are still not ready for widespread deployment.
- growing skills gaps and shortages[15] of qualified engineers, technicians and equipment. For example, skills shortages are recognised as critical for the implementation of the UK's new nuclear build programme[16]. Simple skills movement from other nations will be costly as global demand for engineering talent increases. Also, should the UK be reliant on sourcing skills from abroad to secure its future?
- finally, and maybe the most significantly, markets around the world are simply not that interested. Green energy is expensive and the free market has consistently shown that the cheapest approach is to dig up fossil fuels and burn them. For many nations with pressing socio-economic issues, the green agenda is barely being considered.

Although the conclusion from the Institution's analysis is that the transition of the UK to a low-carbon economy on the scale required by the Act is feasible using known technologies, the magnitude of the engineering task will be unprecedented. It is an undertaking that will need large-scale commitment of human and material resources not seen since the cold war. The big question is, therefore, whether it is feasible to carry out such a task at such a scale in the current socio-economic and political environments? In other words, can we deliver?

CAN WE DELIVER?

A key aspect to effective policy implementation is that policies must meet not only criteria for technical feasibility but also social and political acceptability. Regardless of the theoretical arguments for technical 'feasibility', the targets of the Climate Change Act must also pass the wider test of practical 'do-ability'.

To seek a quantitative assessment of whether the targets and carbon budgets set in UK legislation are achievable within the current socio-economic environment and political frameworks of western democracies, the Institution concurs with the recent analysis of Professor Roger Pielke amongst others[17,18]. Drawing upon the methodology of Waggoner and Ausubel[19] and the so called Kaya Identity, Pielke[17] made plausible assumptions of future economic growth, which by definition integrate future population growth and per capita economic growth (GDP). Pielke then calculated what rate of decarbonisation would be necessary for the UK economy to meet the future emissions target set by the Act. Decarbonisation is defined as reducing the carbon intensity of the economy (that is a reduction in the carbon emissions per unit of GDP). Since the potential for reducing non-CO_2 gases in future years is limited, the need for emission reduction is more pronounced for CO_2 than for all other GHGs.

THE GLOBAL CHALLENGE

To put the UK's engineering challenge in the context of the worldwide engineering task, the International Energy Agency (IEA) has estimated what will be required to meet the overall global target of a 50% reduction of greenhouse gas emissions by 2050 relative to 1990 levels. In this regard, the IEA estimates that every year between 2013 and 2030 the world will have to construct 30 new nuclear power plants, 17,000 wind turbines, 400 biomass power plants, two dams the size of the Three Gorges project and 42 coal or natural gas power plants with Carbon Capture and Storage (CCS) implementation, amongst a plethora of smaller scale facilities. The Institution agrees with the IEA's conclusion that a world project on this scale is unprecedented and notes that the international competition for limited resources of engineers, labour, manufacturing capacity, construction kit and finance will be intense.

The rate of decarbonisation of the UK economy implied by this analysis is 5.5% for the 2050 target. This number is substantially higher than the rates of decarbonisation observed in the UK for the periods of 1980 to 2006 and 2001 to 2006, as summarized in the table below.

	1980–2006	2001–2006	2007–2020	2007–2050
Actual	1.9%	1.3%	—	—
Rate required (at 2% GDP growth)	—	—	4.4%	5.5%

Table 1: Rate of decarbonisation of the UK economy observed (first two columns) for 1980 to 2006 and 2001 to 2006, and implied (third and fourth columns) by the 2020 and 2050 targets (assuming 2.0% future GDP growth).

To achieve the ambitious emission reduction targets set in the Climate Change Act, the UK will need to decarbonise at more than 4% per annum in the short term and at over 5% per annum to 2050. Historically the UK has achieved an average decarbonisation rate of around 2%. At best, in 1992 to 1998 the UK economy decarbonised at a rate of 2.3% per year as a result of the increased use of gas for electricity generation (the so called 'dash for gas'). However, this reached a limit at the end of that decade and the decarbonisation rate fell to 1.3% per annum.

Looking forward, can the UK achieve rates of decarbonisation higher than 4 or 5 percent (or higher) per year in the future? To help assess this question, it is useful to examine the successes of other developed nations.

GLOBAL COMPARISONS

Cross-national comparisons can provide some benchmarks to assess the magnitude of the challenge. **Figure 1** shows tonnes of carbon dioxide per $1,000 of GDP for the United States, China, Germany, Japan, France and the United Kingdom. The United Kingdom, at 0.42 tonnes of carbon dioxide per $1,000 of GDP in 2006, was comparable to Japan in its emissions per unit GDP but less efficient than France. The UK was however more carbon efficient than Germany, and much more so than the United States and China.

Figure 2 shows how each of the six economies have decarbonised from 1991 to 2006, with each country normalised to a 1991 baseline (chosen as the year of German reunification).

Figure 2 shows that the UK's rate of decarbonisation has been much greater than that of Japan, which saw little change over the period. The UK has also been faster than the United States, Germany or France, which have had similar rates of decarbonisation. One important reason for the decarbonisation of the UK's economy has been the large decrease in energy intensive manufacturing as a portion of its economy – from 33% in 1970 to 13% in 2007[20]. China saw its rapid decarbonisation reversed in the early years of the decade. Thus, there is no recent precedent among developed countries with large economies for the sustained rapid rates of decarbonisation required by the Climate Change Act. Such rates must be several times greater than observed in the UK in recent decades, and based on different contributors as the sectoral shift away from manufacturing has its limits.

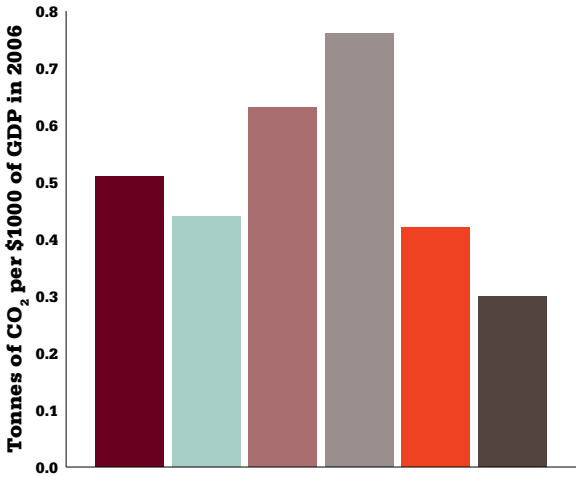


Figure 1: Tonnes of carbon dioxide per $1,000 of GDP in 2006 for Germany, Japan, United States, China, UK and France.

- Germany (0.51)
- Japan (0.44)
- USA (0.63)
- China (0.76)
- UK (0.42)
- France (0.3)

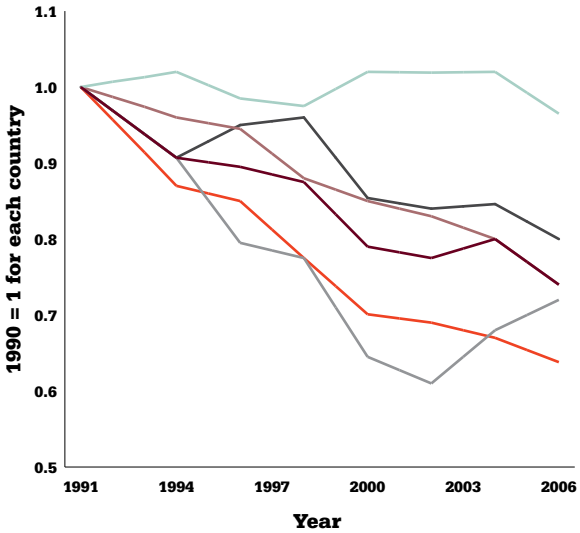


Figure 2: Relative decarbonization for Germany, Japan, United States, China, UK and France, 1991 to 2006.

- Germany
- Japan
- USA
- China
- UK
- France

The major developed economy with the lowest ratio of emissions to GDP is France, which emitted 0.30 tonnes of carbon dioxide per $1,000 of GDP in 2006. France has achieved this level of decarbonisation due to its reliance on nuclear power for electricity generation. France achieved an average rate of decarbonisation of about 2.5% per year from 1980 to 2006, but achieved only about 1.0% per year from 1990 to 2006. It took France about 20 years to decarbonise from 0.42 tonnes of carbon dioxide per $1,000 GDP (the level of the UK in 2006) to 0.30 tonnes of carbon dioxide per $1,000 GDP.

France's decarbonisation experience thus provides a useful analogy. For the UK to be on course to achieve the targets for emissions reductions required by the Climate Change Act our economy would have to become as carbon efficient as France currently is by no later than 2015. An idea of the magnitude of this task can be gained by considering, for example, that this requires work on a scale equivalent to building about 30 new UK nuclear power plants by 2015, displacing coal and gas fired electrical generation. To meet the 2020 target the UK would then still have to decarbonise by an additional 33% in another five years, ie. from 0.30 tonnes of carbon dioxide per $1,000 GDP, to 0.20 tonnes.

AN UNCOMFORTABLE REALITY

Given the magnitude of the engineering challenge and the pace of action required, the Institution concludes that the Climate Change Act has failed even before it has started. The Climate Change Act does have a provision for the relevant minister to amend the targets and timetable, but only for certain conditions. Failure to meet the targets is not one of those conditions. It seems likely that the Climate Change Act will have to be revisited by Parliament or simply ignored by policy makers.

The approach to emissions reduction embodied by the Climate Change Act is, in the opinion of the Institution, back-to-front. It begins with setting a target and then only later do policy makers ask how that target might be achieved, with no consideration for whether the target implies realistic or feasible rates of decarbonisation. The uncomfortable reality is that no one knows how fast a major economy can decarbonise. Both the 2020 interim and 2050 targets require rates of decarbonisation far in excess of what has been observed in large economies at anytime in the past. Simply making progress to the targets requires steps of a magnitude that seem practically impossible, such as the need for the UK to achieve a carbon efficiency of its economy equal to that of France in 2006 in just over five years.

Further analysis shows that if the UK were able to at best match the highest rate of decarbonisation achieved by the nation during the 'dash-for-gas', a significant emissions reduction shortfall will occur as illustrated in **Figure 3**. Even if the country was capable of doubling its decarbonisation efforts after 2050, the Institution calculates that the 80% reduction target will not be achieved until **2100** at the earliest.

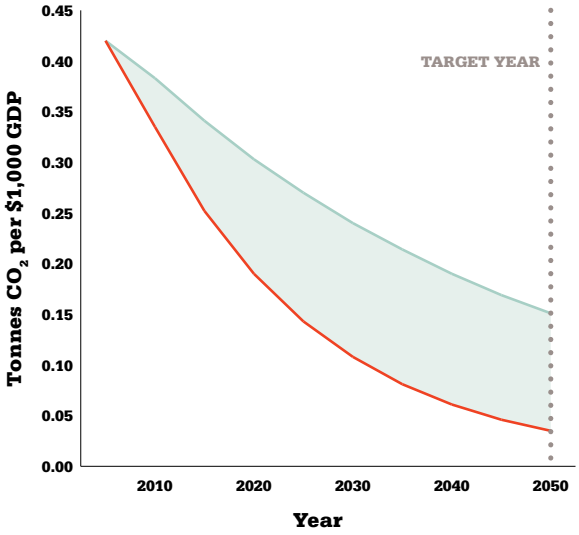


Figure 3: Decarbonisation rates
- Assume 'Dash-for-Gas' rate (2.3%)
- Required decarbonisation rate (5.5%)
- Shortfall in meeting the 2050 target could be made up using geo-engineering. For example, 330MtCO_2 emissions reduction shortfall in 2050 could be absorbed by 100,000 artificial trees (see page 9 of 'Geo-engineering – Giving us Time to Act' report and roadmap page 18)[28].

MITIGATION, ADAPTATION AND GEO-ENGINEERING STRATEGIES NEED TO BE USED TOGETHER TO COMBAT CLIMATE CHANGE.

ESTABLISHING A REALISTIC APPROACH TO CLIMATE CHANGE

Although a growing proportion of the international and UK domestic policy community recognises the likely failure of the Climate Change Act, this has yet to be broadly accepted. However, when it does become apparent that the Act has failed, it will provide an opportunity for western democracies to recast climate change policies in a more effective framework. Some political thinkers are already beginning to debate what policies would work better and stand a better chance of achieving a satisfactory outcome[10].

It is the Institution's view that a new more effective policy approach to global warming and climate change would sensibly take a more realistic approach to **mitigation** and include **adaptation** and **geo-engineering** as integrated components. The question is therefore: can these responses coexist in a coherent policy and what mechanisms are appropriate to the scale of the challenge ahead?

This section examines what can practically be achieved in each of the three areas (Mitigation, Adaptation and Geo-engineering) and then explores how an integrated approach should look for the UK. Since it is in the developed countries that real progress first has to be made, by focusing on public policy at the national level in the UK a substantive framework should emerge that offers coherence and consistency as to how national governments in developed western democracies should cope with the long-term challenges of climate change.

Recommendation 1: Adopt a MAG approach to climate change policy to help reach our targets. The UK will fail to achieve the outcome desired by the 2050 80% GHG reduction target without the adoption of a unified **MAG policy**. This single integrated policy approach would continue mitigation policy (such as decarbonising energy and transport systems) as well as develop effective temporary geo-engineering solutions and an adaptation strategy to protect critical assets from inevitable climate change impacts. This approach would be a world first and offer a possible global route-map for many other nations. The full adoption of a MAG policy could also increase the UK green sector to over **2 million jobs by 2050**, guaranteeing many organisations decades of work reducing emissions and protecting our nation.

ON MITIGATION – GLOBAL ACTION AND NATIONAL SECURITY

A reduction in the global emissions of greenhouse gases should be the key priority to ensure a limited and manageable impact of the climatic changes that will result from global warming. Scientific evidence about the probable rate and intensity of future climate change has become increasingly stark[21] and impacts are likely to be especially severe in the developing world for both physical and social reasons.

While the evidence suggests that the chances of limiting average temperature rises to 2°C or below appears to be rapidly diminishing, this should in no way reduce the importance of mitigation. This is for two main reasons:

1. non-linearities mean that damage increases disproportionately as average temperatures rise ever higher.
2. the mitigation burden can be shared fairly among the world's countries compared to the specific and sometimes acute burdens of adaptation.

Carbon dioxide is considered to be the most important greenhouse gas and decarbonisation of the world's primary energy supplies is therefore a key component in climate mitigation strategy. Decarbonisation of the electricity generation sector offers an effective mitigation policy, especially for industrialised countries. However, a key policy question for governments is can we have climate change mitigation while protecting security of supply? Security of supply is defined as protecting the stream of energy resources (nationally and internationally) and ensuring domestic and industrial supplies are maintained at all times. A nation cannot be held to ransom by external elements for its energy supply (as seen with Ukraine) or operate a successful economy with black-outs (as seen in South Africa and California).

In reality, 'security' is politically easier to frame than 'climate change' and the electoral cycle means that politicians are more likely to give emphasis to energy security. The formation of the Department of Energy and Climate Change (DECC) was therefore welcomed by the Institution as demonstrating a more positive Government commitment to 'joining up' climate change mitigation policy and providing a stepping-stone on the pathway to an effective policy.

Fortunately most technologies that would help with energy security would also be good for mitigation. However, there are specific issues in relation to energy efficiency, renewables and coal:

- while improved energy efficiency is essential, it can sometimes allow wasteful energy uses: the so-called rebound effect.
- renewables are problematic here, though undoubtedly good for mitigation. Their impact on security requires careful assessment (especially because of intermittency), particularly if they reach a significant proportion of total energy supply.
- coal without carbon capture and storage (CCS) is clearly a problem area – it would be good for security but bad for mitigation. It has to be recognised that coal will be used, worldwide, on a large scale for a long time. Development of CCS is vital, both for the UK's industrial benefit and for worldwide mitigation. Establishing early demonstration plants with CCS and subsequent commercial deployment should therefore be a high priority.

There is also a general issue of large-scale centralised technologies (eg. nuclear, CCS, tidal power) versus small-scale local technologies (CHP, wind, biofuels). In this regard the engineering reality is that, given current planning procedures, project lead times, capacity constraints and skills shortages, large-scale technologies will take significant time to take effect. It is therefore essential in the next decade to push ahead with small-scale and decentralised options; subject to them being genuinely low-carbon and not excessively expensive. However, as indicated previously, the engineering and technological challenges of mitigation are on such a scale that the UK will inevitably need a great deal of large-scale centralised technologies to achieve the necessary emissions reductions. Indeed, an inherent characteristic of a continued dependence on fossil fuels with CCS technology will be the need for centralised infrastructure on a substantial scale.

Given the public resistance to many large-scale technologies, Government will need to take a more active, planning-based role in ensuring that relevant technologies can be implemented in a timely way[10]. Several decades of trying to encourage changes in behaviour to achieve mitigation objectives have simply failed (witness the reality of the 30% rise in global CO_2 emissions[22] that has taken place in the 15 years since the UNFCCC came into force – a total failure by governments worldwide to engage the human race in behavioural change). There is too much short-term thinking at all levels in society and no clear long-term strategy. Would we approach an invasion or war with such short sightedness? Strong government leadership is required to highlight the urgency of the problem, the ways needed to solve it, and the possible long-term view of the nation.

In the Institution's view, policy instruments domestically should be as market-friendly as possible but market failures do need to be recognised. In relation to specific policies towards technology development, a 'technology-blind' approach is appropriate at early stages of development. However, on occasion, the Government should take a risk in backing strategically important technologies, such as CCS.

On mitigation policy the Institution of Mechanical Engineers recommends that the Government:

1. changes the language of public discourse on climate change mitigation from that of 'mitigation' to that of 'low-carbon energy security'
2. gives a stronger and more strategic lead in support of short term deployment of small-scale local technologies and in removing barriers to the implementation of large-scale centralised infrastructure
3. gives more urgent attention to the significant opportunities for UK plc in a range of 'low-carbon energy security' technological areas, most especially in large scale infrastructure solutions such as CCS
4. takes the lead in developing a new approach to energy strategy making major decisions using a long-term framework
5. puts in place and maintain stable long-term policies with cross-party support that create investment environments in which commercial organisations can commit to finance low-carbon energy security technology and infrastructure.

ON ADAPTATION – PROTECTING THE GLOBAL COMMUNITY

While mitigation aims to prevent climate change, climate adaptation deals with the question of how to cope with the impacts of climate[23]. However, climate change mitigation and adaptation cannot be treated as alternatives. Instead the right balance between both needs to be found at any given time. In this regard the degree to which adaptation is needed will be a continuously shifting horizon determined by the reality of the effectiveness of ongoing global mitigation efforts.

As a result of previous emissions, and indeed the emissions that will take place in the future while the global community transitions to a low-carbon economy, a certain amount of climate change will be inevitable. For the UK, projections of future climate[23,24] through to the end of the century show a transition to hotter, dryer summers and wetter, warmer winters with an increased frequency of extreme weather events. The Institution recently published a report[23] that illustrated the engineering response required to adapt our energy, transport and water infrastructure, and built environment to such changes. In some extreme cases this would mean planned abandonment of settlements and existing infrastructure.

At a global level, impacts from climate change may result in geo-political security issues driven by widespread drought, desertification and famine (for example 'water wars' or 'food wars'), large numbers of environmental refugees and disrupted trading patterns[25]. Instability, tension and conflict are possible as nation states struggle to maintain access to the resources necessary to support their citizens and protect their borders. Some military strategists are beginning to assess the implications of such outcomes[25] and using climate change scenarios to help plan future responses and equipment needs.

There are also concerns about potential trade-offs between mitigation and adaptation in terms of public spending as well as in terms of political attention. These are centered on fears that funding for adaptation might reduce budgets for taking mitigation measures as a new political reality emerges in response to increasing climate impacts. In this regard it is conceivable that the public agenda might shift towards more immediate adaptation challenges (eg. 'I need to protect my patch') as people demand solutions for emerging problems (such as flooding, overheating, and drought) and there develops an increasing scope for domestic adaptation to take precedence over internationally beneficial mitigation.

At the international level, adaptation efforts are not sufficiently taken into account in political discourse – essentially we have an 'adaptation deficit'. In partial recognition of this security issue, Gordon Brown[26] and the World Bank[27] have both recently suggested that the developed nations should jointly make an annual fund of $100bn available to help developing nations both adapt to climate change impacts and transition to low carbon economies. However, China and other developing nations have suggested that a much larger figure should be made available by industrialised nations, in the order of 1% of GDP.

Wherever discussions lead, in the end there will need to be more of a balanced future approach between mitigation and adaptation. National adaptation strategies will need to be blended with international mitigation agreements and global agreement that one does not substitute for the other.

Ultimately, climate change will need to be seen as a global issue with all societies protected and adapted, not just the ones who can afford to protect their citizens and assets.

In the area of adaptation, the Institution of Mechanical Engineers recommends that:

1. government takes a clear leadership role in ensuring that existing and future infrastructure is resilient to climate change over long-term timescales
2. engineering standards, design codes and regulations are updated to include adaptation requirements
3. the opportunity be given for UK engineering to contribute to the adaptation agenda.

ON GEO-ENGINEERING – ATTACKING CO_2 CONCENTRATIONS

All evidence to date shows mitigation policy has made little to no significant impact on global CO_2 emissions. The poor prospects for mitigation in the near term, makes it increasingly likely that geo-engineering interventions may need to be deployed within the next 10 to 20 years[28]. Geo-engineering methods, however, can only be used in conjunction with continued effort to decarbonise our economies. They are not a complete solution to climate change. In other words, geo-engineering may be necessary in the short-term to escape a climate change disaster and buy us time while we go about the business of transitioning to a low-carbon world. Development research on geo-engineering approaches must therefore proceed urgently, alongside efforts on conservation, efficiency and the transition to low-carbon energy production.

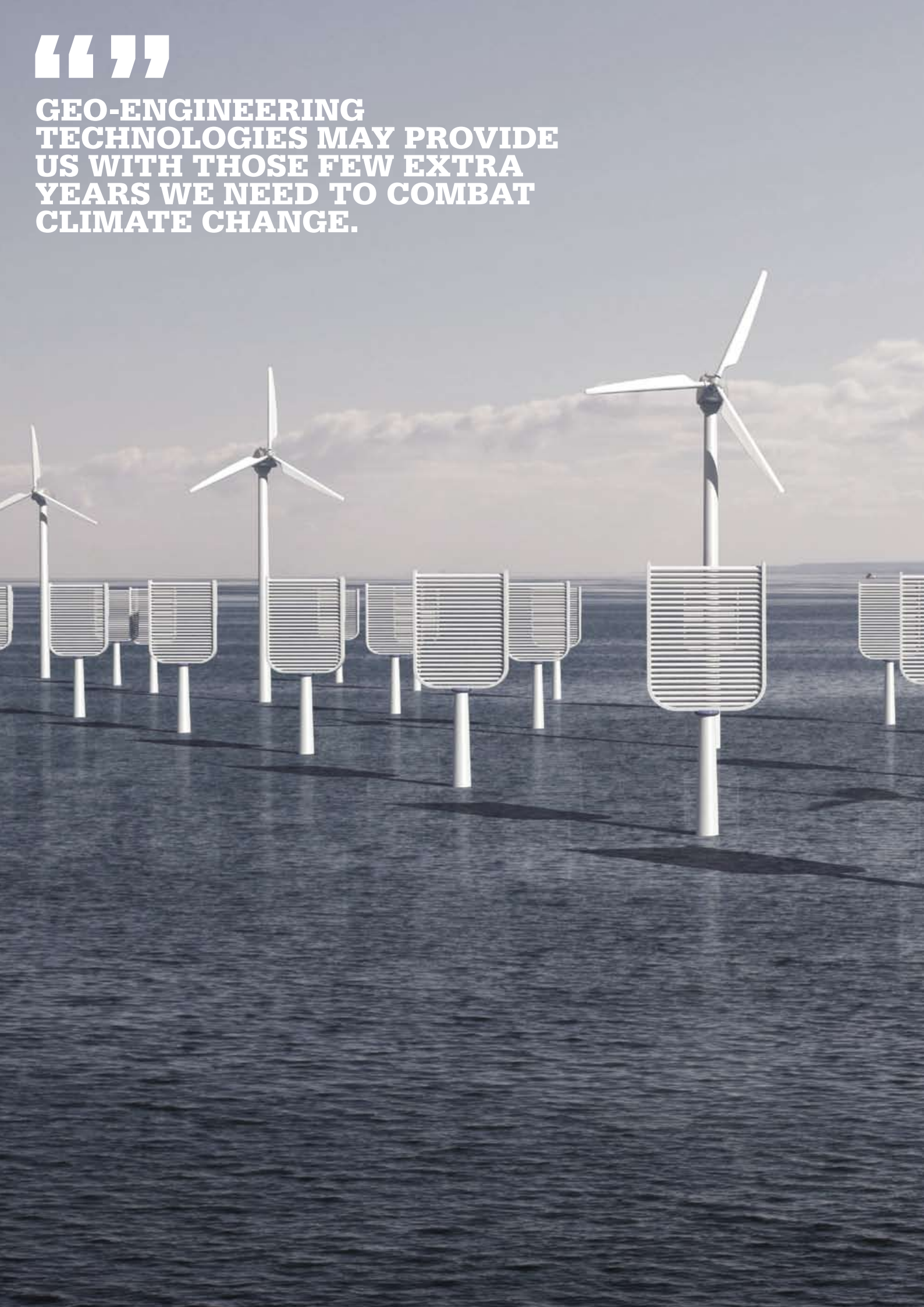
At the current time there is no public funding within the UK for research and assessment into geo-engineering options. Clearly this is a short-sighted approach, both in respect of the lead times that will be required to move from solution concept to operational deployment, and the need for the UK to be an informed participant in any international discussions on the use of geo-engineering. Given recent trends in public R&D funding, it might be very challenging for geo-engineering projects to attract public funding through established mechanisms. It may therefore be necessary to introduce a funding model that has parallels to MOD funding of strategically important military research with long-term stable funding for basic research.

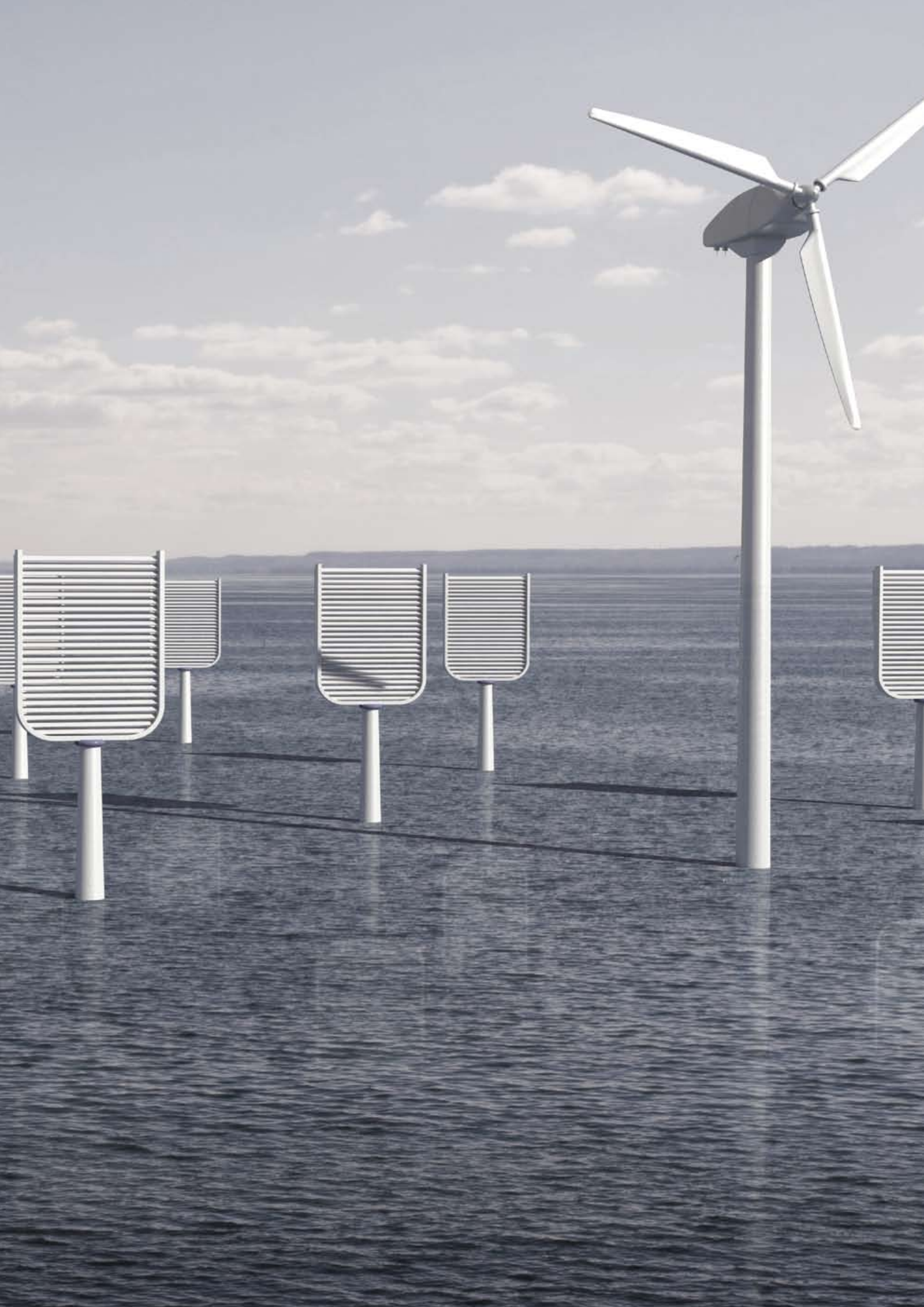
As already noted, geo-engineering is an international issue which will require international agreement. Extensive international collaboration in research would enable a cost-sharing regime to be established. Drawing parallels again from military research projects, particularly the NATO funding model, the establishment of an international body under the auspices of the UN would offer an efficient way forward. Such an agreement could be integrated into other agreements under the UNFCCC.

On geo-engineering policy, the Institution of Mechanical Engineers recommends that the Government:

1. recognises that given the current reality of slow progress in the reduction of global greenhouse gas emissions, there is a need seriously to explore geo-engineering, particularly as a potential option to buy time while mitigation and adaptation approaches to climate change are implemented
2. considers the lead times likely to be needed for bringing geo-engineering approaches from concept to deployment and establishes a targeted funding stream to enable feasibility assessment for a number of options to be undertaken
3. facilitates the establishment of an international framework for R&D work in this area
4. implements pilot schemes that show the most promise through to demonstrator phase to enable their relative potential to be accurately assessed
5. recognises the areas in which the UK is already a world leader and the potential commercial opportunities for UK plc in demonstrating geo-engineering related technologies and put in place supporting policies.

GEO-ENGINEERING TECHNOLOGIES MAY PROVIDE US WITH THOSE FEW EXTRA YEARS WE NEED TO COMBAT CLIMATE CHANGE.





WINNING THE CLIMATE CHANGE WAR

The Institution believes we have almost certainly lost the mitigation battle. We do believe however that we can still win the climate change war. Given the magnitude and timescale of the challenge, a fundemental shift in policy is required where all three approaches (**M**itigation, **A**daptation, **G**eo-engineering) need to be adopted by policy makers in an integrated **MAG** strategy.

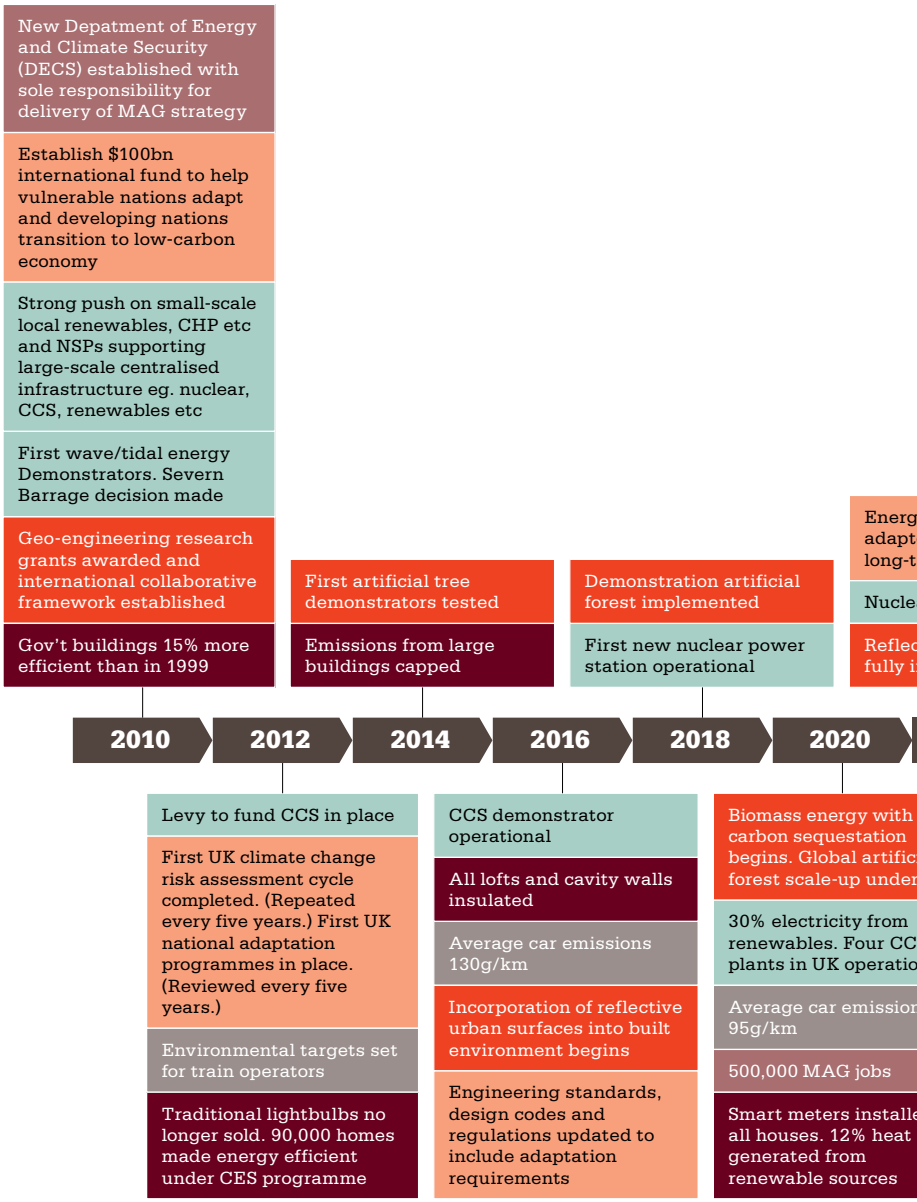
An integrated climate change policy needs to be pulled together at the level of a national strategic plan and a single expert-led body is required with control of R&D spend across the full spectrum of mitigation, adaptation and geo-engineering. Government leadership and integration across approaches and departments is needed. The analysis presented in this report has shown that in the UK there is a mismatch between global ambitions and local achievements and that Government efforts need to be intensified in this area.

To achieve a strong, focussed and common energy and climate strategy, the Institution recommends that all elements of Government responsible for aspects of mitigation, adaptation and geo-engineering should be moved into a remodelled Department of Energy and Climate Change. This new department (**Department of Energy and Climate Security – DECS**) would have the authority to control, direct and prioritise national funding, planning, development, commissioning and implementation of the UK's MAG strategy. In addition, DECS would develop a long term climate change plan based on an agreed vision. It would not be influenced by short-term political thinking.

Recommendation 2: Introduce centralised control for climate change policy. All parts of Government responsible for mitigation, adaptation and geo-engineering activity should be moved into a remodelled Department of Energy and Climate Change (DECC). This new 'security' department (**Department of Energy and Climate Security – DECS**) would have sole responsibility, and the necessary powers, to direct national funding, planning, development, commissioning and implementation of the MAG strategy, having priority above nearly all other departments.

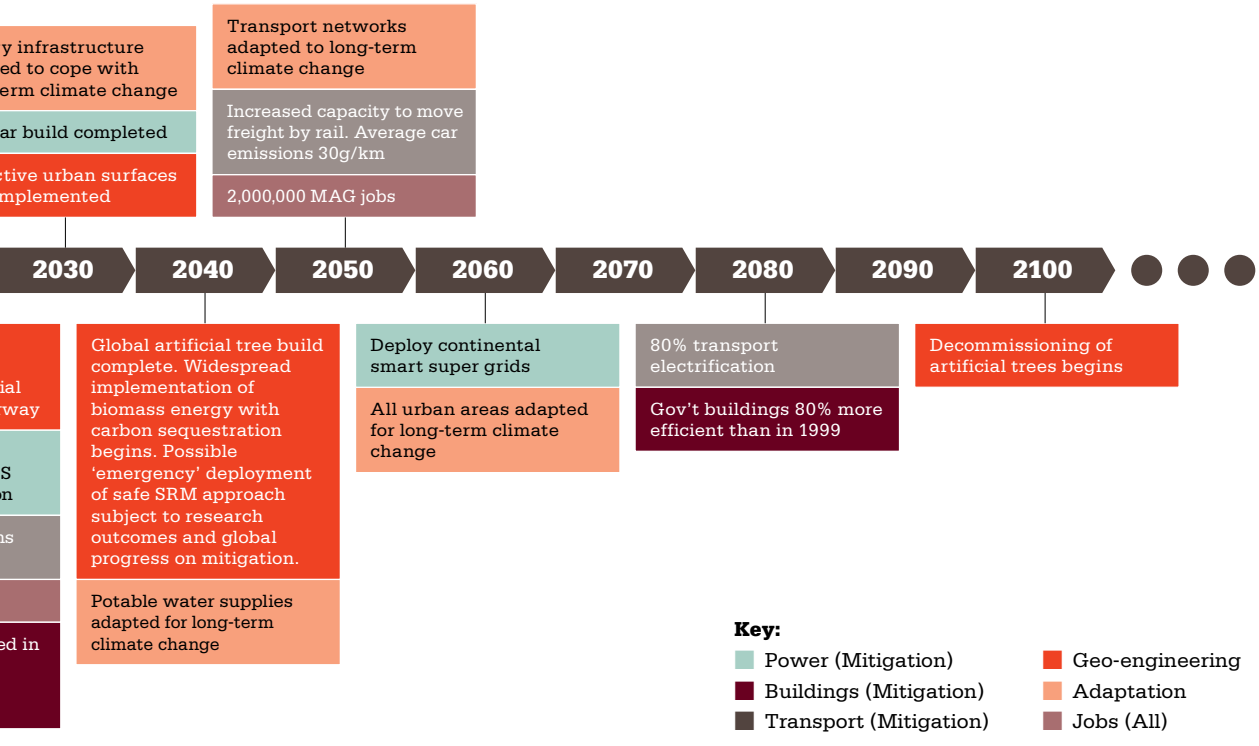
DEVELOPING A CLIMATE CHANGE BATTLE PLAN

Building on knowledge acquired through rigorous comprehensive evidence based assessments and MAG related R&D programmes, the Institution recommends that a national battle plan to MAG implementation be devised. Based on the Institution's analysis to date, such a plan might include the following elements over a 75 to 100-year timescale:



- Integration of all elements of Government responsible for aspects of mitigation, adaptation and geo-engineering into a remodeled DECC (renamed DECS) charged with delivery of a MAG policy approach
- Strong short-term push on small-scale local low-carbon technologies (renewables, CHP etc) and National Policy Statements (NPSs) supporting delivery of large-scale centralised infrastructure (nuclear, CCS, renewables etc)
- Establishment of an international annual $100bn fund for assisting vulnerable countries in adaptation and transition of developing nations to a low-carbon economy
- Funding provision for geo-engineering research established together with international collaborative framework
- Decarbonisation and expansion of global electricity generation capacity, including deployment of smart supergrids on a continental scale
- Parallel research and development of electric transportation technologies and technologies for decarbonisation of dispersed sources
- Parallel implementation of air capture geo-engineering approaches, such as artificial forests leveraging emerging CCS infrastructure for storage and algae on buildings biomass schemes
- Possible 'emergency' deployment of Solar Radiation Management (SRM) subject to research outcomes and progress globally on transition to low-carbon economies
- Phased electrification of transportation sector and dispersed sources of CO_2 emissions
- Continued use of air capture geo-engineering to clean up past emissions until atmospheric CO_2 concentration returns to a climatically acceptable level
- Decommissioning of geo-engineering solutions

Recommendation 3: Develop a comprehensive MAG battle plan to a secure future and help industry plan future skill requirements. The Government should work with the engineering profession and business community to develop a comprehensive plan for the implementation of geo-engineering and adaptation alongside the transition to a low-carbon economy. This plan should be scaled over at least 100 years or until the geo-engineering element is eliminated.



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