PRINCIPLES TO DETERMINE GLOBAL AND NATIONAL EMISSIONS REDUCTION TARGETS[1]

“It is the mark of an educated man to look for precision in each class of things just so far as the nature of the subject admits” [...] “To the youthful and to the morally incontinent, knowledge [of ethics and political science] brings no profit; but to those who desire and act in accordance with a rational principle, knowledge of such matters will be of great benefit.”
– Aristotle[2]

“Actions speak louder than words”
– Traditional proverb

How fast do we need to reduce our greenhouse emissions for a secure future? Targets for reductions in greenhouse gas emissions are derived, consistent with a fair chance of avoiding dangerous climate change. Specifically, targets that imply at least a 50% chance of global temperature rises exceeding 2 Celsius above the pre-industrial level are recommended[3]. A methodology is proposed for translating between a global target and a national target, based on diffusion of climate change policy and low-carbon technologies.

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2 (1980, p.4)
3 As agreed by the European Union and many countries worldwide (UNFCCC 2009).

CONTENTS

Emissions Targets[4]

What Are Emissions Targets?

Emissions targets specify the intended future trajectory or cumulative budget of emissions of greenhouse gases. Emissions targets may be set at a global level, or at the scale of a political unit such as the nation state. Targets are intended to guide policy and provide a greater degree of certainty over future direction.

Static and Cumulative Targets

The purpose of setting targets for reducing global CO_2 (eq.) emissions is to comply with two goals. First there is the need to stop global warming by preventing the relentless rise of greenhouse gases. But stopping global warming by an agreed date is insufficient; it is even more important to keep the warming below a limit on dangerous anthropogenic interference in the climate system and this depends on the accumulated emissions of CO_2(eq) i.e. the area under the emissions versus time graph.

Enforcement of Targets

Targets can be rigidly enforced, approximately enforced or not enforced at all. Approximately enforced targets can be as often over achieved as underachieved. For example, many central banks have the inflation rate as a target and the interest rate as the tool to achieve that target. Climate change targets could be enforced (rigidly) by an upstream emissions permits system or by a carbon tax that is gradually adjusted to meet the target (a 'tax-to-target' scheme).

Dangers of Targets

Some targets have their dangers and we need to be careful to avoid them. In this case the danger is that the target could lead to complacency and perhaps place a barrier between policy and the research which lies behind it. This is particularly important in the case of global warming because the risks of getting it wrong are so great. Targets can also be a substitute for meaningful action. Governments set a target so as to be seen to be doing something; they then often ignore it and then readjust the target, perhaps making future targets stronger. Targets are not enough. Real policy changes affecting the real economy are required. However, we still need to know approximately on what time scale and what sort of action is required.

Adaptive Targets

Targets are inevitably a balance between what is necessary to prevent climate change and what is possible in a modern society. But we may *not* know in advance either what is necessary or what is possible. If we try to stick to targets too rigidly, we may lack the flexibility to abate emissions fast if it turns out to be easy or if climate change turns out worse than expected. We may need policy that allows us to overachieve on our targets. When dealing with the real political battle of climate change, we should take note that the benefits of tackling climate change accrue on a global basis, whereas the costs of tackling climate change exist on a national level. Here we assess what is necessary on a global scale and then we assess what that would mean from a national perspective, and finally whether such targets are technically and economically feasible on a national scale.

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4 For example, in the 2009 G8 summit in Aquila, Italy, the leaders gathered there backed:

- A 50% reduction in global emissions by 2050 (CNN 2009)
- “A broad scientific view that global warming should be limited to below 2 Celsius above pre-industrial times” (Reuters 2009)

Methodologies for Determining Targets

Emissions targets are in principle a balance between two factors:

- firstly, the risks and damages associated with climate change, some of which we could avoid by rapid emissions reductions;
- second, the costs or benefits and technical feasibility of reducing emissions at different rates.

There are three sorts of justification that we could bring to bear:

A) An analysis based purely on climate science deriving a *required* emissions reductions rate to avoid dangerous climate change, or to keep damages below a certain, critical level.

B) An analysis based on the *expected capability* of the economy to reduce emissions, deriving a *possible* emissions reduction rate;

C) A *mixed analysis* that balances both the expected behaviour of the climate and the expected capability of the economy.

In the next two sections, I will consider two possible approaches to balancing the costs and benefits of action, *cost-benefit analysis* and *risk analysis*.

Cost-Benefit Analysis

The main tool used by economists to evaluate public policy is Cost-benefit analysis (CBA). Cost-benefit analysis assesses both the *costs* and the *benefits* of a proposed policy. Costs and benefits are measured in terms of *welfare, which itself can be defined as the gain expected from a project.*

Cost benefit analysis implies a certain decision rule. If the (risk-adjusted) expected benefits of a proposed project or policy exceeds the costs, the economist's recommendation would be that the policy or investment should go ahead; if the (risk-adjusted) costs exceed the benefits, the economist's recommendation would be that the policy or investment should not go ahead[5].

The theoretical foundation for cost-benefit analysis is outlined in Dasgupta (2001).The CBA decision rule is formally equivalent to the criteria that a project or policy increases *wealth*, where wealth is defined as the *social value of capital assets*. This can be compared to the decision rule of a company which is whether a project makes a *profit,* which is to say increases the wealth of the company's owners, where wealth is defined as the private value of capital assets, plus any cash or financial claims on others. Cost-benefit analysis for the policy maker[6] is equivalent to a financial assessment of the expected addition to profit or loss of a project to a company, but with *social* values rather than *private* values considered. So, in summary, the CBA decision rule is simply to go ahead if our societal valuation for something is positive. CBA merely shifts the frame of decision making into the realm of *social valuation*. But determining social valuation is no mean feat.

The *Stern review* contains the most serious form of CBA. The Stern review suggested that we should pay approximately 3% of GDP in order to achive benefits valued at 5-20% of GDP. As such it recommended emissions reductions consistent with stabilizing greenhouse gas concentrations in the range 450-550ppmCO_2^e (400-490ppmCO_2), and a price on carbon of \$85/tCO_2.

Difficulties With Cost-Benefit Analysis

There are the following major questions about cost-benefit analysis, specifically in the context of the Stern Review:

- The lack of a global government and therefore the importance of the benefits and most importantly, the costs of climate change action to individual agents;
- The appropriate discount rate to use;

5 For a review of Cost-Benefit analysis is available in Perman et al. (2003)

6 Assuming such an individual exists.

- The appropriate way to value the risk of catastrophic events.

Collective Moral Incontinence and Anarchy at the Global Level

Cost-benefit analysis typically assumes that there is a state able to enforce its will. But the problem of climate change is a *collective action problem*. Nevertheless, even without a global government, it might still possible to set up cost-benefit analysis as a *global ethical* analysis as to whether the world *should* tackle climate change. Self-interest may be as important here as morality. For more details see Gardiner (2006).

The Discount Rate

The question as to the appropriate discount rate appears to be an open one, with fundamental disagreements between economists and between philosophers. Whilst Stern's choice of a low discount rate could be justified on utilitarian or Kantian ethical grounds, economists or Humean ethicists might choose a different assumption. It seems that deciding on a discount rate is one of the most important factors governing the outcome of our cost benefit analysis. Economists have criticised Stern's analysis for relying on the choice of a low discount rate in order to justify action. However, there is a factor which dominates the discount rate: the question of risk.

Valuing the Risk of Catastrophic Events

Weitzmann (2007) argues that Stern is “correct but for the wrong reasons”, In particular, he argues that the benefit of tackling climate change is dominated by the benefit of a reduced probability of catastrophic climate change. Weitzmann therefore cautions against over-reliance on cost-benefit analysis. Work since the Stern review suggested that, in a risk-based framework with risk aversion, the benefit of tackling climate change may be dominated by the *risk avoided* (Weitzman 2008). Whilst the assumptions in the Stern review, especially over discount rate, have been questioned by many, Weitzmann's approach has suffered far less criticism and has been endorsed by many on either side of the discuount rate debate.

We will later find that the risks of dangerous climate change, even under stringent mitigation measures, are higher that we would hope. *C*onsideration of the numbers involved can give us an assessment of the *increase in risk* for a certain emissions path. Whilst we may not be able to eliminate risk, we may be able to value the *reduction in risk*.

Assumptions

A final difficulty with using cost-benefit analysis is the clarity of the assumptions used and the concern that CBA has not achieved polticial legitimacy. We will then consider the question 'how fast is needed to avoid the most serious risks' and 'how fast is possible, given the economic and political situation'.

This has the advantage that 192 countries under the United Nations Framework Convention on Climage Change, have agreed to stabilize greenhouse gas concentrations, thereby *avoiding dangerous anthropogenic interference in the climate system.* Instead of bringing a whole set of unclear assumptions to bear on the problem we will assess the targets which seem to appear necessary to avoid dangerous climate change and then see what appears to be possible in a modern market economy. By assessing what is necessary to avoid dangerous climate change and then assessing what appears possible, we will come to a reflective conclusion as to the correct target to be put in place.

After determining the global target, we will attempt to attribute this to individual nation states. It is vital not to lose sight of the global picture while considering national targets. The global aims must be to avoid Dangerous Anthropogenic Interference (DAI) caused by global warming and also to limit the “acid ocean effect” caused by the solution of carbon dioxide (CO2) in sea water. The EU’s working definition of DAI is any warming above 2 degrees Celsius compared to pre-industrial (1750) levels. We have already used up about 0.8 deg. C of that with about 0.6degs.C committed warming in the pipeline (independent of additional emissions). It's necessary to fully link our emissions target trajectories to the impacts of climate change.

What is Necessary for a Fair Chance of 'Avoiding Dangerous Climate Change'?

The emission of greenhouse gases on the current scale is a clear and present danger to the future of life on this planet. A stabilization target and approximate descent path for global greenhouse concentrations should be agreed in accordance with the **following principles:**

1: Stabilizing Greenhouse Gas Concentrations

It should comply with the UN Framework Convention on Climate Change's (U.N. 1992) overall objective to stabilize greenhouse gas concentrations.

2: Avoiding 'Dangerous Climate Change'

As also agreed at the summit, the target should also avoid 'dangerous anthropogenic interference' with the global atmosphere ('avoiding dangerous climate change'). Even if there is some uncertainty about the science, if we can, we should, surely, act to cut GHG emissions, as no harm will probably be done if its a bit unnecessary and hopefully good will be done if it is needed.

3: Definition of 'Dangerous Climate Change': 2ºC above pre-industrial temperatures

Many scientists suggest (e.g. see (Schnellnhuber & Cramer 2006)) that rises in the global average temperature should be limited to 2 Celsius above the pre-industrial level. Note that Hansen et al. (Hansen et al. 2006) argues that dangerous climate change is an increase in temperatures of 1ºC above 2000 levels or 1.8ºC above pre-industrial levels[7].) The 'two degrees' target has been adopted by the European Union (European Commission 2005).

For the time being, we define dangerous climate change as a temperature rise of 2ºC above pre-industrial levels consistent with the EU definition.

4: Target Probability of Avoiding Dangerous Climate Change

Since climate science involves multiple uncertainties it is not enough to decide upon a target; we also need a target probability of achieving those goals. However, the lack of a politically defined target probability for achieving the two Celsius target means that it is difficult to translate a 2C target into a stabilization level and therefore to an emissions reduction pathway.

5: Stabilization Level of Global Greenhouse Gases

The Stern Review recommended stabilization of all greenhouse gas emissions in the range of 450-550ppm CO_2 equivalent. CO_2 alone needs to be stabilized at or below 450ppm.

Hansen now suggests that we have *passed* what constitutes a dangerous concentration of CO_2 in the atmosphere. He suggests that we now need to return to 350ppmCO_2^{only}.[8]

Many climate scientists have also argued for the notion of cumulative targets in regard to 350ppmCO_2e (Carbon Dioxide Equivalent) 400ppmCO_2e or 450ppmCO_2e. The final concentration depends heavily on the path taken and not just the final point.

6: Target Reduction in Global Greenhouse Gas Emissions[9]

We have already determined that if we are to stabilize greenhouse gas concentrations, then we will

7 This is the maximum at the last interglacial – any higher and we risk 'seeding irreversible effects'.

8 Others (e.g. see Joslin 2009, forthcoming) suggest that to avoid the planet 'cooking', returning to pre-industrial levels 180-280ppm CO_2 would be a better bet.

9 With other greenhouse gases in net balance, so that the difference between CO_2 forcing and total forcing is approximately equal to the present level.

need to reduce greenhouse gas emissions (to be precise, to less than 7 Gigatonnes of CO_2 per year). This is an *85%* reduction in current **total** global greenhouse gas emissions. To stabilize carbon dioxide concentration, emissions need to fall below 7 Gigatonnes per year. To stabilize total radiative forcing, other greenhouse gas concentrations also need to stabilize; and so emissions must fall to the net out flow. The IPCC think we need to do this by 2050. I will argue a little later that we should act more rapidly (Also see Anderson & Bows 2008)

The G8 communiqué mentions the EU and Japanese target to reduce greenhouse gas emissions by at least 50% by 2050. The UK target needs to be consistent with this goal.

7. Cumulative Target

There is a danger associated with having a single simplistic target where more than one is needed. Consider for example a motorist who finds that his accelerator jams at a high level just when he sees a cliff in front of him. His speed is 30 metres per second and the barrier is 600 metres away. Someone advises him to set a target of stopping within 16 seconds during which he has to free his accelerator and apply the brakes. The fault here is that the target mentions the final speed (zero) and the time, but not the distance travelled which is equal to the area under the speed versus time graph. That distance must be less than 600 metres. If there is any delay in taking action it may be possible (in theory) to meet the target but not to avoid the wall. It must be of some concern that the 60% target for carbon dioxide emissions fails to mention the accumulation of carbon dioxide which will be produced between now and the target date.

To achieve at a maximum 50% chance[10] of keeping global temperature rises below two degrees Celsius above the pre-industrial level, global cumulative emissions of CO2 for the 21st Century remain below 1 trillion tonnes of CO2. 30% of the budget has already been used up, leaving 600 billion tonnes left.

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10 *Of course a merely evens chance of avoiding potentially catastrophic damages would seem to be far too high, but may be the best that is possible now.*

Deriving a National Target

In addition to global targets, it may also be useful to consider national targets[11].
In order to translate between global targets and national targets we need to use some principle to translate between the two. The Royal Commission on Environmental Pollution report (Royal Commission on Environmental Pollution 2000) recommended the use of the principles of 'Contraction and Convergence' developed by Aubrey Mayer of the Global Commons Institute (Mayer n.d.). By assuming a date where all global emissions converge, the model assumes that the whole world converges to a single per-capita level of emissions.[12] Under these assumptions it is also possible to derive a global emissions target. Sicne the RCEP report, C&C has become the de-facto standard for translating between a global and a national targets.[13]

Convergence: Why?

We divide the world's nations into leaders, and followers.

- Leaders reduce emissions relatively fast. If we wish a 'mean response' to climate change to fit the 'contraction and convergence' model, then the leader's response must be to cut emissions faster than the model suggests.
- Follower will reduce CO2 once it is shown that it is not too politically or technologically difficult to do so or will need to be shown that it is in their selfish interests to reduce emissions.[14]

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11 National targets allow us to relate the overall requirements to reduce greenhouse gas emissions to the scales at which the most significant political activity is primarily located, the national scale. In order to do this, we need an 'allocation principle'. One commonly used such principle, known as 'contraction and convergence'.

12 What is contraction and convergence (C&C)?

C&C is a set of principles for distributing emissions rights amongst countries around the world. C&C suggests that

a) global emissions should be reduced to the levels necessary to stabilise global greenhouse gas concentrations (contraction).

b) rights to emit greenhouse gases should be allocated on a per capita basis. Over time, the amount allocated per person should smoothly move from current levels to an equal per-capita level (convergence).

c) if a country emits more than it's allocated quota, that country would need to buy permits from those countries who emit less than their allocated quotas.

Contraction

Contraction Path is a smooth graph consistent with this set of 5 parameters:

- Existing emissions
- Convergence level of global emissions
- Cumulative Emissions between now and then
- Existing rate of change
- Rate of change at convergence point

This defines a global contraction path.

It is not just the contraction path that is relevant, it is also the cumulative emissions between now and the convergence point.

Convergence

Global emissions are planned to converge at a particular date in the future. Hopefully, the UK smoothly transits from the current level of emissions to a fair share of global emissions.

13 The system of contraction and convergence outlined by Mayer requires five different parameters. It is possible to considerably simplify this system as follows, in order to allocate a cumulative budget for example for the 21st century, for example by allocating the global budget according to existing emissions. Using this system it is possible to give back of the envelope calculations of the permitted budget.

There are two problems with this approach:

1. It implicity assumes convergence to zero, a possibly unrealistic assumption
2. It is unfair on countries with low existing emissions.

14 A potential criticism of this classification is that countries are not represented by a 'representative country'. In the real world, some countries might actually need to **increase** their emissions to reach a 'contraction and convergence'

Leaders set a moral and technical model that others might follow ethically & diplomatically. Collective effort will probably be less than that of the leading nation (this is mathematically true if we define the leading nation as that with the steepest descent path). There is some evidence for copycat behaviour in international politics. Bans on smoking in public places, first taken up in countries such as Ireland, spread across Europe. Peer pressure and the need not to be 'left behind' in a new trend may be motivating factors. When faced with a question with an unknown answer – especially one such as 'what should I do' – looking at what other people are doing is often a key piece of evidence. People are cautious of the new; demonstrating a new way of doing things may lead to people copying it. What is a reasonable lag between the leaders of the pack and the laggards? We suggest that the leaders should reduce emissions 10-15 years before the average country, and 20-30 years before the laggards. When calculating the emission reduction needed to make a particular concentration target, we must account for this lag too.

The idea of leaders and laggards re-frames our questions of urgency. One suggestion is that we should set 2050 as a target for achieving this target, nevertheless this is the target for the whole world. Certain countries may wish to see themselves as 'leaders'; for these it is necessary to cut emissions more rapidly than the target suggested by 'contraction and convergence'. For any given reduction in emissions, to achieve a certain stabilization level, leading nations may need to reduce their emissions faster than required by 'contraction and convergence' if the world in aggregate is to achieve stabilization at any given level of greenhouse gases. The lag between the leader and the laggard might be as much as 20-30 years.

Convergence: When?

It is questionable how realistic is the assumption that the whole world converges on a particular per-capita emissions level at a single date. Real convergence of emissions and economic system, unlike ideal convergence, is likely to be highly imperfect. Far from suggesting that sharp cuts are impossible, political realism in fact suggests that we need to make cuts *faster* to take account of the lag involved in adoption of these technological-economic model in other parts of the world. If the developed world does not act rapidly, it may lose the leading role in low-carbon technology entirely.

The above analysis assumes that other countries will converge on emissions in a complete and equitable fashion. An alternative assumption is that some countries (particularly the developing world) will 'wait and see' for the developed world to introduce a non-CO2 dependent way of life, before doing so themselves. In this, more pessimistic view, global emissions will only converge on that of a 'climate leader' after some delay. It may be necessary for the UK to 'show the way' early, to avoid locking in a large amount of CO2-intensive infrastructure in China and similar countries. Our emissions have been compared (Flannery, 2006) to the development of cancer in the human body: they may reach a stage where it is simply not possible to turn it around.

An alternative proposal for translating between a global cumulative budget and a national emissions budget is developed here:

1. Define the cumulative budget. Subtract any emissions prior to the date where contraction is expected to commence. Equals the remaining cumulative budget.
2. Define the global floor emissions; Allocate floor emissions on an equal per capita basis for the whole period. This constitutes the floor emissions.
3. Subtract the floor emissions from the remaining cumulative budget. The remaining emissions are the convergence emissions, allocated according to *existing budget*
4. Allocate the convergence emissions as follows:
    1. Determine the proportion x of total emissions covered by the leader levels

level. These countries can arguably converge more rapidly than currently expected. This criticism is not valid because emissions and potential emissions are rising very rapidly in the *developing* world. It may be just as difficult for these countries to reduce the rate of growth than for developed countries to reduce their emissions in absolute terms.

2. Define the convergence time from the total budget by assuming a linear reduction from current levels
3. Assume that leader nations will immediately reduce emissions whereas follower nations would immediately stop the increase in their emissions – but will only start absolute declines once the leader nations have reached their core emissions.
4. The leader's convergence time would then be a proportion of the total convergence time.

Feasibility of Rapid Cuts in Emissions: What is Reasonable?

In the light of the above, it might be that engineering principles could be used. One such principle, used to regulate radioactive emissions, is known as “As Low As Reasonably Achievable” (or “ALARA”). We might augment this with “As Quickly As Possible” (AQAP). The question is: what is reasonable?

Time scales consistent with carbon-intensive infrastructure renewal

We can get some idea from the lifetime of typical large-scale infrastructure of one to a few decades (Stern 2006). In the UK and similar countries, many large power stations are over half way through their lives; which suggests a complete renewal in twenty or so years is not impossible if we start building now. Much large scale infrastructure (power stations, railway rolling stock, buses) require renewal over a time scale of 10-30 years. A rapid decarbonization target would, in effect, outlaw the creation of new carbon-intensive infrastructure.

Time scales consistent with historical examples

There are many historical examples of reductions in carbon emissions but many of them are associated with economic collapse (the Great Depression; the collapse of the USSR). A couple that are not are associated with changes in fuel mix in electricity generation: in particular, the 'dash for gas' in the United Kingdom, and the expansion of nuclear energy in France. A typical Frenchman emits around 6.5 tonnes of Carbon Dioxide per year; this can be compared to a German or a Brit, where the figure is 10 or 11 tonnes of CO_2 per year. The task of climate change can be approximated as doing 3 or 4 times what France achieved; but working on a number of different fronts (e.g. including other forms of low-carbon energy, such as renewable energy, energy efficiency, electric cars). We will come to energy policy in later chapters.
Other historical examples of fast economic transformation include UK mobilization before WWII and US mobilization for WWII after Pearl Harbor; as well as the development of railways in England in the nineteenth Century and the development of mobile phones in the late twentieth century. Transformation of tax codes has happened in the 1980s.

Time scale consistent with non-delay of essential governmental decisions

With very rapid decarbonization, the government would be forced to treat the problem with a degree of urgency that is required at some point to solve the problem, since there would be literally no time to waste. Every year delay would, in effect, delay the outcome by one year.

Timescale consistent with the effect of carbon prices

The timing of emissions reductions appears a question that the market might presumably be able to determine. In order to find this out, the government could impose a relatively high carbon tax, and see what happens. There remains the question about what exactly is reasonable and relatively high. A useful marker might be the level in terms of carbon to the oil price jump from the early 2000s to 2007.

Discussion

It is not known how fast it is possible to reduce emissions, even given a set of assumptions over what sort of governance structures are in force. It would therefore be useful to model the transition to a near-zero carbon society over twenty years, using commonly-used modelling tools (e.g. the Markal model used for the UK Energy Research Centre's Energy 2050 project).

Conclusions

In the absence of global governance or 'burden sharing' structures, it is argued, on three grounds, that emissions reductions for 'leader nations' in the developed world must be more rapid that those of the 'follower' nations.

1. Some nations will be more committed to solving climate change than others; mathematically, the leader nations must reduce emissions more strongly, so that the average emissions reduction rate is consistent with the overall global target.
2. Most countries, it is argued, will have a 'wait and see' attitude: they will want to see that it is demonstrated that reducing emissions is economically feasible and low-cost.
3. The United Nations Framework Convention on Climate Change argues for 'common but differentiated responsibilities', usually taken to mean that the existing high emitters in the developed world must lead.

It is not known whether rapid decarbonization is possible (given background assumptions), and if so, the relevant costs. Because of this uncertainty, it might be sensible to find some mechanism to infer the information from the market. Although *energy system costs* are likely to be higher, there is also evidence *of wider macroeconomic benefits* to GDP and employment from rapid decarbonization strategies (Terry Barker & al. 2009; T. Barker & Jenkins 2007).

The stakes are very high. It should be noted that without this leadership, there is a much higher risk that the level of carbon-based infrastructure will be so high, that, far from reaching the 2 Celsius target, it may not be possible to stabilize greenhouse gas concentrations at all.

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