Energy demand and the 2°C commitment

Choice-editing the car market: radical reductions without reinventing the wheel

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The Context

With large-scale impacts of climate change increasingly discernable from the background of natural variability, so concern is rising over the global community's failure to control emissions. The International Energy Agency (IEA) captures this pivotal moment in history, when noting that *"The current state of affairs is unacceptable … energy-related CO_2 emissions are at historic highs"* [1] and emission trends are "perfectly in line with *a temperature increase of 6 degrees Celsius, which would have devastating consequences for the planet*" [2]. In similar vein a growing chorus of academics are increasingly allying current emission trends with temperature rises of 4°C to 6°C by the end of the century.

Today, in 2014, we face an unavoidably 'radical' future. We either continue with rising emissions and reap the radical repercussions of severe climate change, or acknowledge that we have a choice and pursue radical emission reductions; no longer is there a non-radical option. Moreover, low-carbon supply technologies cannot deliver the necessary rate of emission reductions – they need to be complemented with rapid, deep and early reductions in energy consumption – the rationale for this paper.

From global to Annex 1 emissions

The IPCC's fifth assessment reports (AR5) from Working Groups I and III were the first since the IPCC's inception to explicitly include the concept of carbon budgets. Budgets constrain the total cumulative quantity of carbon dioxide that can be emitted between specified dates and for defined probabilities of avoiding the 2°C characterisation of dangerous climate change. As such they equip policymakers with the quantitative framing of mitigation required to meet the international community's 2°C obligation to *"hold the increase in global temperature below 2 degrees Celsius"* and to do so *"consistent with science"*[1]. However, the international community has also and repeatedly recognised the imperative to apportion the limited carbon budget on the *"basis of equity"*[2]. Consequently the scale of mitigation demanded of wealthier and more industrialised 'Annex 1' nations will be greater than that required of poorer and less-industrialised 'non-Annex 1' nations.

The IPCC reports do not explicitly disaggregate the range of 2°C carbon budgets between Annex 1 and non-Annex 1 nations. However, a small set of equity-based assumptions applied to non-Annex 1 emissions give a clear and quantitative framing of the mitigation efforts necessary from the wealthier Annex 1 countries. In 2014 and with high levels of global emission growth already locked in to the energy, land-use and industry sectors, at least until 2020, the implications for Annex 1 mitigation rates of any reasonable equity criteria are well beyond anything yet countenanced.

For the mean WGIII carbon budget accompanying a "likely" chance of not exceeding 2°C, and assuming non-Annex 1 nations peak emissions by 2025 before mitigating at around 7%p.a., then, as a guide, Annex 1 nations need to mitigate at rates of over 10% p.a., starting immediately.[3] This rate could be reduced if non-Annex 1 nations had still more challenging mitigation, but even with the 2025 non-Annex 1 peak, the apportionment of the global 2°C budget already and significantly favours Annex 1 nations.[4]

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[1] This specific form of words was first used in the Copenhagen Accord [3] and thereafter in modified forms in international agreements including those forthcoming from Cancun, Durban and Doha as well as the G8 Camp David Declaration [4].

[2] The Copenhagen Accord expressly notes, "the time frame for peaking will be longer in developing countries".

[3] This framing is based on Anderson Bows [5] where they use a 2000-2100 carbon budget of 1321GtCO2 Their choice of budget is sufficiently close to the mean WGIII (2011-2100) budget of 905Gt (once the 2000 to 2010 emissions of ~330GtCO2 have been added) for their assumptions to be valid for the analysis here.

[4] Factoring twentieth century emissions from Annex 1 nations into calculations of the 'fair' emission space available for Annex 1 in the twenty-first century would leave Annex 1 nations already in 'emission debt'. Whilst such an outcome may have some moral legitimacy, it evidently would not provide for a politically consensual framing of emission apportionment. However, the implications of including twentieth century emissions and the concept of emission debt may guide the scope and scale of climate-related financial transfers (arguably as reparation) between Annex 1 and non-Annex 1 nations. Jiankun et al [6] make the case that "reasonable rights and interests should be strived for, based on the equity principle, reflected through cumulative emissions per capita". Building on this cumulative emissions per capita approach, the authors demonstrate how China's historical cumulative emissions are only one-tenth of the average in industrial countries and one-twentieth that of the U.S.

In the medium- to long-term low-carbon energy supply technologies will be a prerequisite of a decarbonised future. However, they cannot penetrate the energy system to the levels required to deliver the immediate and deep cuts in emissions necessary for even an outside chance of avoiding the 2°C characterisation of dangerous climate change. What is absolutely clear is that radical reductions in emissions from Annex 1 nations, delivered over the coming decade, necessitate radical reductions in absolute energy demand. Moreover, non-Annex 1 nations must avoid locking in high-carbon behaviours and routines as well refraining from investing in inefficient technologies that, in a low carbon future, would rapidly become a stranded asset.

This context is itself unparalleled. But if poorer nations are to have any opportunity to develop and improve the welfare of their citizens, then their emissions will, at least in the short term, inevitably rise. Within a highly constrained 2°C carbon budget, this puts still greater pressure on the wealthy nations to reduce their energy consumption. Whilst this paper proceeds to illustrate the substantial scope for rapid reductions in emissions from a mix of end-use technologies and changes in behaviours and routines within Annex 1 nations, the analysis also holds in relation to limiting the rate of growth of emissions within the developing and newly industrialising nations.

Best available technology

Efficiencies vary widely for energy consuming technologies in many key sectors, with the best-available-technology (BAT) for some technology types using only a fraction of the energy of the average unit currently in use. Against a backdrop of voluntary agreements by manufacturers and EU directives on product energy efficiency, recent decades have seen a strong trend for improving energy efficiency across the board, from consumer electrical goods, to passenger cars and houses.

Nevertheless, the best available models still make up only a small proportion of new purchases in the majority of sectors where consumer preferences include factors other than energy efficiency. In the UK passenger car sector for example, cars in tax band A (emitting less than 100gCO_2/km) made up less than 4% of new car sales in 2011 [7]. Penetration of BAT is similarly slow in the domestic appliances sector, where A++ rated fridge-freezers made up only 0.5% of sales in 2010 [8]. Similarly A++ rated dishwashers made up around 5% of sales in 2011[8], and A++ rated washing machines around 7% of sales in 2010 [8].

In each case, the more efficient technology is widely available commercially and – on a like for like basis – carries no significant price premium. Purchasers typically face a disorienting and vast array of new products to choose from, with varying levels of additional 'nice to have' features over and above basic product functionality. Furthermore, lifetime running costs are seldom accounted for in purchase decisions, and (tacitly) subject to discounting. With little evidence of significant price sensitivity to long term running costs, energy efficiency, therefore, tends not to feature highly in the list of purchase considerations for key energy consuming technologies [9].

The following section comprises an extrapolation of the potential reductions in energy demand and emissions that could be achieved within a decade through a rapid penetration of BAT in two key energy consuming technology markets: passenger cars and fridge–freezers.

Passenger cars: context

Passenger transport has become both a symbol and prerequisite of contemporary industrial society, with terrestrial demand serviced principally by private cars alongside an important, though much smaller, public transport sector. Whilst in many mature industrial economies the rate of growth in car transport (measured in vehicle kilometres, VKM) has gradually reduced, this is being more than compensated by rapid growth in the newly emerging economies.

Reducing the absolute emissions burden from the high and growing levels of car demand is essential if any reasonable framing of the 2°C carbon budget is not to be breached. Certainly there is significant theoretical potential for technological regime change, substituting mass transit alternatives for private car transport.[5] Public transport has previously served, in various guises, as the dominant transport mode for many, if not all, fledgling industrial societies.

Today passenger cars account for a substantial proportion of emissions from all industrialised (Annex 1) nations and increasingly also from industrialising (non-Annex 1) nations. In the EU (and UK), for example, cars are responsible for one in eight tonnes of all CO_2 emitted, whilst in the USA they represent between 12 and 16%[6]. In China, though emissions from transport are rising rapidly, those from passenger cars are currently in the region of 1.5%[7], but with growing and more widespread affluence this is set to increase at an unparalleled rate [12].

Since 2012 EU regulations have required car manufacturers to improve the emissions performance of their cars such that by 2015 they will deliver an EU wide fleet mean for new cars sold of 130gCO_2/km[8]. This then will subsequently be tightened to deliver a 95gCO_2/km fleet mean by 2021. Whilst on the face of it such legislation appears simple to interpret, in practice industry lobbying has successfully persuaded policy makers to embed a series of measures designed to weaken significantly the original vision of the standards. Under the current regulatory framework, manufacturers whose fleets comprise heavier, typically higher powered, vehicles get less stringent emissions targets than makers of lighter, typically lower powered, vehicles. Manufacturers receive a nominal fine for each gCO_2/km by which they exceed their fleet mean emissions target (*on a per car sold basis)*. They also are afforded a degree of latitude for each ultra-low emissions vehicle (ULEV) they sell; that is, each car with exhaust emissions less than 50gCO_2/km (usually electric vehicles). In 2014, for each ULEV sold manufacturers are permitted to sell 2.5 high emitting cars (without affecting their mean fleet emissions); this is set to fall to 1 to 1 ratio by 2016. Further derogations permit small volume and niche manufactures to negotiate their own (less stringent) emission targets.

While the EU new car regulations and voluntary agreements that preceded them have undoubtedly brought down mean new car emissions at a faster rate in the last decade than the previous decade, they are a much watered down version of the regulations originally tabled by the EU. The car industry lobbied hard and exerted considerable political sway to reduce the stringency of the originally proposed test cycle emissions target of 120gCO_2/km [13], and to incorporate a range of derogations and allowances that effectively render the fleet mean target as 140gCO_2/km [14]. However, repeated arguments by manufacturers that efficiency improvements at the proposed rates would entail prohibitive costs [e.g., 15] have ultimately proved unfounded [16]. In the UK for example, over 320 model variants with emissions below 100gCO_2/km are now available, as are over 150 model variants emitting less than the 2021 target of 95gCO_2/km [17]. Moreover, 82% of these lower-emission vehicles are conventional internal combustion engine (ICE) vehicles, comparable in price to their less efficient equivalents. Efficiency improvements have typically been achieved through reductions in overall vehicle mass by using lighter materials; reductions in engine displacement; aerodynamic enhancements; lower rolling resistance tyres; and retuning performance characteristics away from rapid acceleration and high top speeds.

Importantly, sub-95gCO_2/km options are available in all principal product categories from 'supermini' to 'family estate'; though this has not been achieved in the high performance (and heavier) 'executive' and 'sports utility' categories [18]. As such, in return for reductions in extreme 'top-end' performance, that is in any case redundant for safe driving on public roads,

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[5] 'Alternatives' here refers specifically to the basic function of moving people from 'A to B'. It does not refer to the range of more intangible and psychological functions of car ownership.

[6] 12% for cars only and 16% if light trucks are included, many of which are used as passenger cars [10].

[7] Estimates for China are not readily available. Here an approximation has been made based on a range of sources, particularly IEA [11] and earlier work by Wang *et al* for the U.S. Department of Energy [12]. The IEA estimate road transport oil consumption of 171Mtoe in 2011, of which, Wang *et al* imply approximately 20-22% can be attributed to car use. So in 2011 cars represent around 35Mtoe, which is approximately 105MtCO_2 i.e. around 1.5% of the IEA estimate of China's 2011 emissions.

[8] Based on the mean kerb weight of their annual sales fleet and assessed over the NEDC test cycle for new cars in 2015.

the diverse transport needs of car drivers may be met by low emissions vehicles at no significant price premium.

In addition to the ICE powered cars on which this analysis is premised, there is substantial scope for both plug-in hybrid and fully electric power systems to further reduce car emissions, with the technology of the former now well developed. In terms of fully electric cars, there remain significant range issues to be resolved, but for many shorter journeys (under 150km) there are a small but growing number of commercially available models delivering gCO_2/km similar in emissions to their best ICE counterparts. The actual level of reduction depends, in large part, on the emissions intensity (gCO_2/kWh) of the generating system. In France, with its nuclear dominated grid, "well to wheel" estimates are under 20gCO_2/km [19]; whereas in the UK and much of the EU, with mixed-generation supply, fully electric cars achieve around 75 to 100gCO_2/km. In countries where electricity is generated primarily from fossil fuels, electric vehicles have considerably higher carbon intensities per kilometre than the best available small internal combustion vehicles [20]. If the 2°C threshold is not to be breached, electricity generation must undergo rapid decarbonisation, with accompanying reduction in gCO_2/km from electric vehicles. However, for this analysis, fully electric cars are not considered a significant part of the mix, and as such the reductions discussed here are in some respects technologically conservative.

Passenger cars: delivering early & deep mitigation

Aligning stringent 2°C carbon budgets with the experience and policies of the EU with respect to car emissions provides a framework within which the sector could make its fair contribution to a serious mitigation agenda without wholesale socio-technical regime change. Building on the approach by Calverley [21], the following steps illustrate options designed to maintain the current level of car travel, but to do so with substantially lower emissions. Option 4 increases the fleet emission reductions still further, but does so at the expense of reduced levels of car transport.

1) establish a fleet mean (or maximum[9]) emission standard for all new cars, set at a level[10] already met by commercially available vehicles at little-to-no price premium.
   Note: as referenced earlier, there are many internal combustion engine vehicles at sub-95gCO_2/km available on today's market[11].

2) increase the rate at which cars are replaced such that there is much more rapid penetration of the lower-emission vehicles.
   Note: in the UK, for example, 62% of all vehicle kilometres travelled is by cars of eight years or under. The careful application of a scrappage scheme could be used to increase this ratio; the use of annual vehicle checks with tightening gCO_2/km standards and financial inducements to switch vehicles could be considered.

3) develop a suite of policies to compensate for the inevitable rebound impacts of more efficient cars.
   Note: such policies would need to be flexible as rebound issues are notoriously difficult to predict, and the non-marginal scale of changes suggested here would likely result in responses not envisaged and to which policies would need to adapt (See Box 1).

4) improve 'conservation' as well as efficiency; i.e. deliver an absolute reduction in aggregate vehicle kilometres travelled.

[9] A maximum level would likely face higher-profile opposition, but would deliver additional benefits as celebrities and other role models were forced to become early adopters of low-emission technologies, with the accompanying benefits of normalising such change and further driving the innovation process. In addition if the emission reductions sought are perceived to be causing widespread hardship, they are more likely to receive support if the accompanying effort is seen to be fairly distributed, rather than a particular elite simply being exempt from having to make noticeable adjustments in their choices, lifestyles etc.
[10] In absolute, not vehicle mass-weighted, terms.
[11] The standard should not be prescriptive about the type of technology, but in the case of electric vehicles, it would need to account also for the emissions associated with generating the electricity, rather than focus on solely on 'tank-to-wheels' emissions.

Note: this could be through policies to increase number of car occupants in mean journeys (the bulk vehicle occupancy level) or through reductions in the number of journeys considered necessary.

Using the UK to illustrate the potential of such strategic mitigation demonstrates an emission reduction in just ten years from introducing a 95gCO_2/km standard of around 50%, other things being equal[12]. Complementing this with a scrappage scheme specifically tailored at substituting the higher with lower carbon emitting vehicles could, depending on the details of scheme and subsequent distances driven, increase the reduction still further.

Assuming the necessary policies are in place to negate any rebound implications, then a further reduction of 20% in aggregate vehicle kilometres travelled across the fleet by 2025 would bring emissions down by almost 60%.

Such reductions relate to the UK and much of the EU, where the existing fleet and current models are considerably more efficient than their counterparts in the USA, Canada and Australia. According to provisional estimates from the US Environmental Protection Agency [22] new personal vehicles[13] sold in 2013 are likely to have mean emissions of 230gCO_2/km. This follows a very clear, though only recent[14], trend in reducing emissions for new models in the US, with emissions in 2013 down 18% on those a decade earlier. The current emissions factor for all US personal vehicles (taking account their different annual distances travelled for different age and emission categories, etc.) will be considerably higher than the new model mean of 230gCO_2/km.

Whilst the average annual distance each vehicle is driven in the US is reducing, it still remains above that in the UK and Germany (around 20–24,000km against 13–16,000km). Occupancy rates, however, do not appear to be significantly different; though accurate rates across the spread of distances travelled remain poorly estimated. Nevertheless, if the essential purpose of personal transport is to move people and their required possessions safely across distances of a few to many hundreds of kilometres, the scope for rapid and very deep reductions in emissions from car transport in the US is significantly greater than that for the EU. Very approximately, if the US were to follow similar efficiency improvements to those outlined above for the UK and EU, it could deliver in excess of 60% reductions in its total car emissions in ten years. Add to this a continuation of the downward trend for typical distances travelled, and reductions of over 70% would be viable in around a decade.

Undoubtedly such a mitigation strategy for the car sector would face a barrage of vociferous opposition from both the industry and those with a vested interest in the status quo. In addition, libertarian arguments would likely be levelled at such direct intervention. However, if avoiding the 2°C characterisation of dangerous climate change is to be a central pillar of policy, all sectors will be required to deliver reductions far in excess of those previously countenanced, and the car sector is no exception. The suggestions here endeavour to minimise the overall changes to current travel patterns and technologies. Ultimately however, if the industry is unwilling to deliver on the scale and urgency of the reductions necessary, more ambitious policies with fundamental repercussions for travel will be required if emissions are to remain within the 2°C carbon budget range.

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[12] Faster rates of fleet turnover could be achieved by offering incentives to hasten the retirement of older, higher emitting cars in favour of new BAT models, but further emissions savings from such a scheme depend largely on the implementation of supporting policies to guard against rebound effects. Specifically, new cars are typically driven considerably further than older cars; hence it is important to ensure that incoming vehicles are not used more than the vehicle they replace.

[13] The EPA adopts a clear definition of personal vehicles that includes both cars and some light trucks (with four wheel drive SUVs and pick-ups coming under the latter category). The 230gCO_2/km (370gCO2/mile) estimate assumes 64% cars and 36% light trucks, emitting respectively 202 and 281gCO_2km (325 and 452gCO_2/mile).

[14] Between 1980 and 2003 carbon emissions from new models remained relatively unchanged at around 280gCO_2/km (450gCO_2/mile). Only in the last decade have emissions begun to reduce.

Extrapolating Cars to Refrigerators

Fridges and freezers are the single biggest energy consuming domestic appliances in most households, responsible for around one in six units of domestic electricity consumed (excluding heating), and amounting to 5% of total UK electricity demand [23]. While typical fridge and freezer purchases have shown a slight decline in energy consumption over the last decade, most of this improvement in performance has been outweighed by consumer preferences for selecting larger fridge-freezer units.

These trends in capacity and energy consumption belie the headline improvements in energy efficiency of new fridge-freezers. Since July 2012 UK appliances must have an energy rating of at least 'A+' (products with ratings of A and below no longer being offered for sale), although the rating is for energy efficiency per litre capacity not absolute energy consumption.

Currently around 25% of fridge-freezers in use are over ten years old [24]. If those UK households that have not replaced their fridge-freezer in the last ten years were to do so with a modern highly efficient appliance of a capacity similar to pre-2004 models (rather than the larger sized models more recently fashionable), their cold appliance electricity consumption could be reduced by around 12%. However, fewer than 2% of all fridge-freezers currently in use in the UK are rated A+ or better, with over a fifth of appliances consuming more than three times the energy each year of the best available units[15]. Therefore, a more stringent but technically and commercially viable option, would be to have a phased replacement of all appliances rated A+ and below with A+++ units[16]. Other things being equal, and again assuming no net rebound, fridge-freezer annual energy consumption could be reduced by around 60% on aggregate.

As with cars, this substitution of BAT for currently inefficient fridge-freezers need not attract a significant price premium and could be delivered through implementation of a maximum energy consumption standard[17] for new products in combination with a scrappage incentive scheme.

Headline messages:

(a) The fifth set of IPCC reports (AR5) are the first to provide an explicit carbon budget range for a *"likely"* chance of not exceeding the 2°C characterisation of dangerous climate change (630-1180GtCO_2 between 2011-2100)

(b) Allying this budget range with even a weak interpretation of the equity dimension enshrined in the Copenhagen Accord and international climate commitments since, demands wealthy industrialised (Annex 1) nations begin an immediate programme of radical mitigation at rates far beyond anything yet countenanced (~10% p.a.)

(c) A Marshall plan for decarbonising energy supply is necessary but not sufficient for staying with the 2°C carbon budget range; alone it will fall far short of the required rates *and* timescale of mitigation.

(d) Radical and immediate reductions in energy demand by Annex 1 nations is therefore a prerequisite of an equitable response to the 2°C commitment. Non-Annex 1 nations must substantially reduce the rate of growth in their emissions, reaching a peak by around 2025.

(e) Such early rates of Annex 1 mitigation are viable across many realms of energy demand using existing and commercially available technologies that require no infrastructure investment and attract little-to-no price premium. At a system level such technologies may offer substantial economic benefit in terms of reduced national fuel consumption, reduced dependence on imports, improved energy security and better local air quality.

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[15] Around 1% rated A+ (mean annual consumption 270 kWh; 79% rated A (mean annual consumption 413 kWh); 14% rated B (mean annual consumption 542 kWh); 5% rated C (mean annual consumption 709 kWh) [24].

[16] Average annual consumption of A+++ units 173 kWh.

[17] In absolute, rather than per cubic litre, terms.

Ultimately staying within the 2°C carbon budget range demands two core strategies:

1) A radical and immediate reduction in absolute energy demand by Annex 1 nations over the coming decade, alongside significantly reduced rates of growth in energy consumption by non-Annex 1 nations.
2) A Marshall plan to complete the transition to a zero carbon *energy*[18] system during the 2030s for Annex 1 nations and 2050s for non-Annex 1 nations.

Whilst the Marshall plan for zero, or very low, carbon energy supply is reliant on unprecedented infrastructure investment and ongoing technical advances, the accompanying reductions in energy demand are technically, economically and commercially viable now. The success of 2°C therefore hinges on policy makers and civil society having the courage and audacity to take on those commercial and societal interests maintaining the status quo; compared with decarbonising energy supply, this is an easy ask.

BOX 1: Rebound

The rebound implications of rapid and deep reductions in vehicle emissions are not amenable to accurate prediction and will likely change over time. Whilst most drivers are relatively disinterested in emissions per kilometre (gCO_2/km) of their vehicle, they are likely to respond to a significant decrease in journey fuel costs; typically with some increase in overall distances travelled. Moreover, the rapid penetration of new low-emission vehicles into the fleet will see many drivers of used / second hand vehicles owning new and more efficient models. Historically, those purchasing new cars have tended to have higher annual mileage than those owning older vehicles; a situation that could potentially be exacerbated by the lower fuel costs of the new models.

Any rebound effect of a rapid transition to low-carbon vehicles will have direct repercussions for the level of emission reductions achieved and indirectly risks a degree of modal shift from public to private transport. Consequently, if the intended benefits of the transition are to be realised, policies will need to negate, or at least appreciably alleviate, such rebounds. Given the unpredictable and dynamic response to a rapid and significant change in the fleet, governments would need to draw on a suite of policies that can be adapted to rebound effects in whatever form they become manifest. The most appropriate policy options vary nation by nation, depending not only on the rates of change and demographics of car use, but also according to cultural, political and socio-economic circumstances.

In the current economic Zeitgeist, some form of fuel price adjustment may be appropriate as a means of effectively maintaining the price per kilometre travelled. Economic instruments range from a simple blanket carbon tax on fuel, through to more sophisticated variations in fuel prices depending on the quantity purchased over a given period (i.e. progressive pricing related to litres of fuel bought). Alternatively, more direct quantitative constraints could be applied through rationing, with the potential for some of form of linked trading scheme. Tolls could be levied on major roads and more cities and towns could adopt emission charges or no-car zones – with the effect of discouraging increased car use. However, to provide more than a few examples here risks being policy prescriptive. Measures to negate rebound effects may be informed by analysis, but would ultimately be a *political* decision.

[18] Not just electricity

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