Illustrated implications of the Terrifying New Math of Meinshausen and McKibben

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Abstract: There is a limit to the quantity of greenhouse gases that may be emitted to the atmosphere if catastrophic climate change is to be avoided. The practical implication is that most of the world's fossil fuel inventory must be left in the ground and not burned. The article analyses the implications of adhering to the carbon budget in terms of the implied rate of reduction in emission intensity of the world economy. The world economy must be decarbonised by 2050. The four major emitting countries are examined for their energy and emission policies, their emissions and the trajectories of their required emission intensities derived. This shows how sharply emission intensities will need to be reduced when present policies expire, particularly in Russia and China. The postponement to concerted international action to 2020 increases the costs of action. But barriers to a comprehensive international agreement on limiting emissions still exist. It seems likely that countries will continue to be free to pursue policies for the maintenance of economic growth as a priority. The cost of renewable energy, particularly solar, continues to fall. The market, rather than regulation, may transpire to be the main driver of decarbonisation.

I. INTRODUCTION

In 2009 scientists published a seminal paper that estimated the probabilities of exceeding a 2^{o}C temperature rise for given levels of greenhouse gas emitted between years 2000 and 2050. The paper also carried a fossil fuel inventory identifying the extent of fossil fuel reserves and the carbon dioxide emissions that would result from their combustion (Meinshausen et al. 2009).

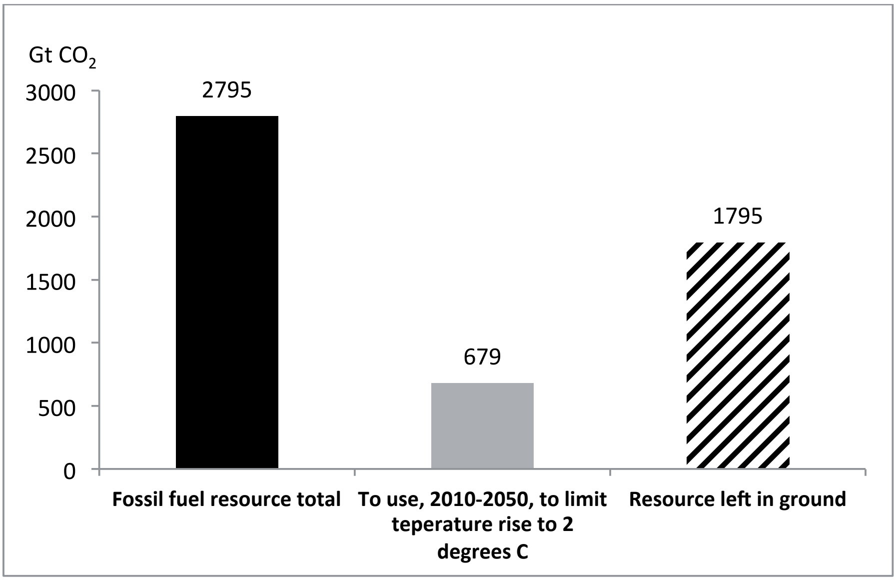
The aim of this article is to illustrate the implications of adhering to the carbon budget by modelling the implied rate of improvement of emission intensity (emissions/Gross Domestic Product) required of the world and the four major emitting countries.

II. THE CO_2 BUDGET

For a 75% probability of remaining within a 2^{o}C temperature rise only 1000 Gt more CO_2 (the main greenhouse gas) can be emitted by year 2000. However, 321 million tonnes of CO_2

were emitted between years 2000 and 2010 (Friedlingstein et al. 2010). This leaves a budget of only 679 GT until 2050; that is, three quarters of the inventory must be left in the ground, see *Figure 1*.

Figure 1: The Carbon Budget with a 75% Chance of not Exceeding a 2°C Rise in Global Temperature



Sources: Meinshausen et al (2009), Friedlingstein et al (2010).

The enormity of this challenge took a while to sink in – too long for US academic Bill McKibben who published "Global warming's terrifying new math" in *Rolling Stone* (McKibben 2012) and in the same year undertook a speaking tour of the US, UK and Australia and New Zealand with the same theme. By doing the maths publicly he made the science plain that only a fraction of the fossil fuel inventory can be used if severe climate change is to be avoided.

Since then much has been written about the CO_2 budget (see for example *The Economist* (2013)), the need to stay within it to avoid the global threat and the prospects of doing so. Institutions have begun taking notice. The International Energy Agency (IEA) (2013) agreed that most fossil fuels must be left unburnt and the World Bank (2013a), another institution with a major global presence, adopted a policy of not lending for more coal-fired power plants and approving gas plants only as transitional energy sources.

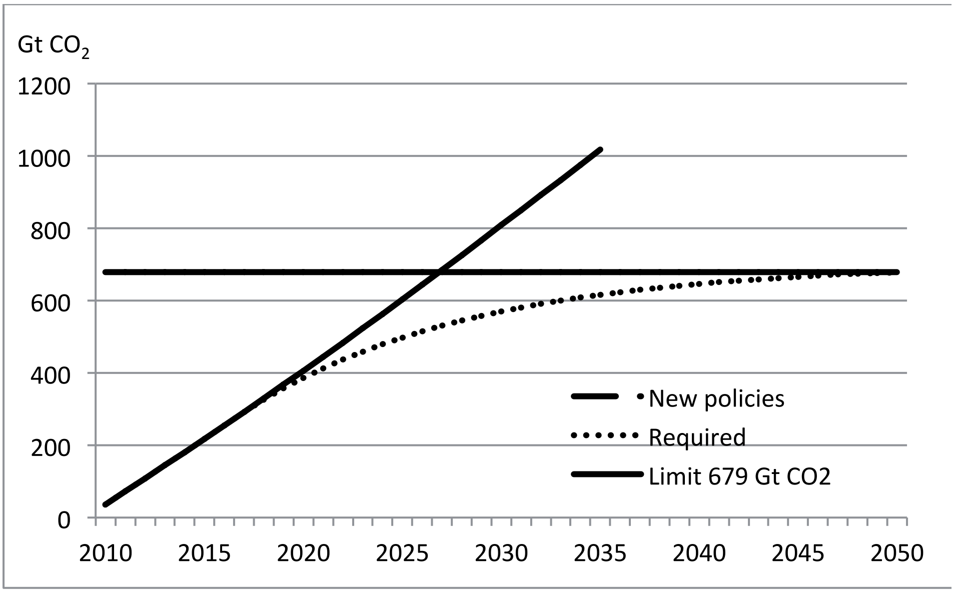
In the next section the trend in global CO_2 emissions is compared with the path that needs to be taken if emissions are to be contained within the CO_2 budget. The task is then expressed in terms of rate of decarbonisation to be achieved by the world economy.

III. GLOBAL DECARBONISATION

The "new" climate policies of countries have been translated into a trend in emissions to 2035 by the IEA (2013).[1] Little deviation is expected from the path of rising emissions. This trend is expected to lead to a long term average temperature increase (compared with pre-industrial levels) of between 3.6 °C and 5.3 °C, with most of the increase occurring this century.

The emissions trajectory required to stay within a 2°C rise, in contrast, is one that takes a downward trend, ensuring that more than 679 Gt of CO_2 is emitted by 2050, as illustrated in *Figure 2*.

Figure 2: Global Emissions Trajectory Expected from New Climate Policies of Countries Compared with Trajectory Required to stay within 2°



Sources: IEA (2013), Meinshausen (2009), Friedlingstein (2010).

To achieve the level of decarbonisation required, consistent with the burning of only 679 Gt CO_2 by 2050, a much greater rate of improvement in efficiency will be necessary. The rate of improvement will depend on the timing of the beginning of the commitment to the target. The longer the delay in action the greater the rate of efficiency improvement required.

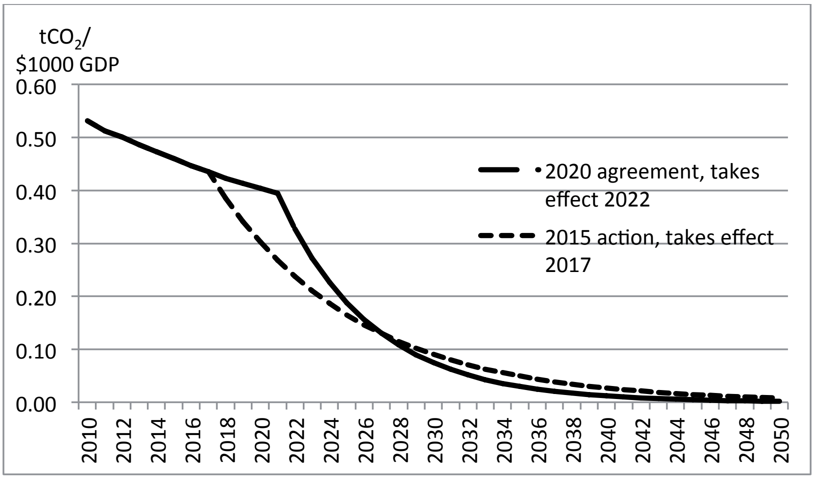
In the analysis, CO_2 emission intensity is derived as follows. Emissions of CO_2 include those from land use change and forestry and are sourced from WRI (2013); while Gross Domestic product (GDP) is at purchasing power parity (PPP) at constant 2005 values, sourced from the World Bank (2013b).

1 The New Policies Scenario takes into account not only existing energy and climate policy commitments but also assumed implementation of those recently announced, albeit in a cautiousmanner (IEA 2013).

The GDP of the world economy is expected to grow at 3.45% annually, which is the rate achieved between 2000 and 2012. Gains in energy efficiency and hence in emission intensity are greatest in the early years, but the CO_2 budget of 679 Gt CO_2 is progressively depleted. In 2050 the budget is exhausted and at the same time the world economy is almost completely decarbonised.

At the Durban UN Climate Change Conference a decision was made to draw up a blueprint in 2020 for a fresh, universal legal agreement (UNFCCC 2013a). Assuming that such an agreement can be reached and effectively implemented by 2022, implies a continuous improvement in emission intensity in the face of economic growth. The rate of reduction in emissions intensity necessary with a delay in action to 2020 is considerably greater than if earlier action takes effect in 2017, as illustrated in *Figure 3*.[2]

Figure 3: Emission Intensity of the World's Economy to stay within 2°C



Sources: WRI (2013), World Bank (2013b).

Whether such rapid decarbonisation of the world economy is achieved will depend largely on the energy and emissions policies and actions within the four countries responsible for 68% of greenhouse emissions: China, the U.S, India and the Russian Federation. The next section summarises the present policies of each of these countries as a background to forecasts to 2020.

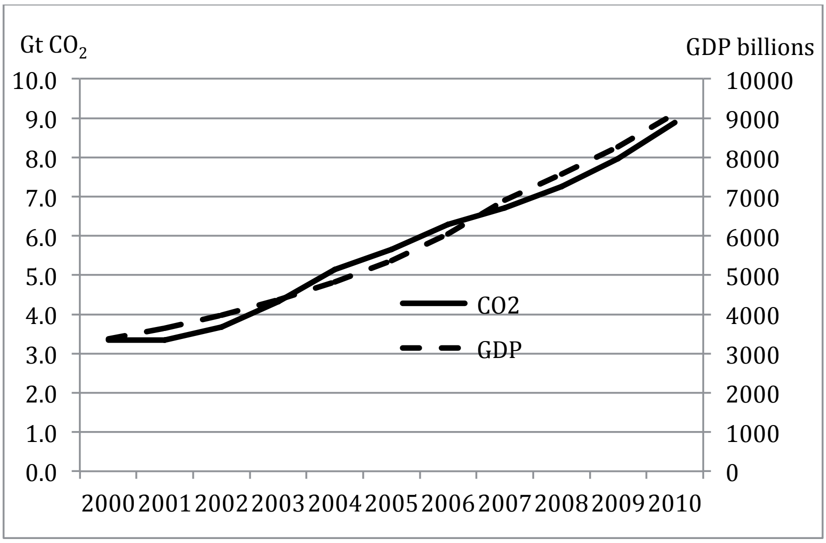
[2] Where B = emission budget
E = annual emission
J = years, 1-50
Emissions in any one year is derived as follows:
Ej = Bi /1-1/(1+i)j
And emission intensity in any one year is derived as follows:
EIj = Ej/GDPj

1V. POLICIES OF THE FOUR MAJOR EMITTERS

4.1 China

Even though its economy was only half the size of that of the U.S., China overtook the U.S. as the world's greatest emitter of greenhouse gases in 2006. *Figure 4* shows that emissions and economic growth have remained strongly coupled over the decade 2000-2010 due to the country's continuing reliance on coal as a source of energy. If the rate of increase in emissions between 2000 and 2010 is not reduced China will use up 64% of the entire carbon budget by 2050. However, there is a great deal of latent improvement in energy efficiency to be exploited.

Figure 4: China: Emissions and GDP, 2000-2010



Sources: WRI (2013); World Bank (2013b).

Figure 4 shows that China's emissions are tightly linked with economic growth. This is the likely reason why China and India – where emissions and growth are also strongly correlated (*Figure 6*) – have always opposed emission reduction targets *per se*.

China's 12th 5 year plan mandates that emissions per unit of GDP will decrease by 17% between 2011 and 2015 (Peoples Republic of China 2011).This will be achieved by increasing the contribution of gas, hydro and nuclear to the energy mix and building ultra-high voltage (UHV) transmission lines. And China's State Council has stopped approving new coal fired plants in northern eastern and southern China, urban pollution concerns being one of the drivers of this policy (Wall Street Journal 2013).

Meanwhile, however, the construction of coal-fired plants is being accelerated elsewhere under the 12th 5-year Plan – in northern Shaanxi, Huanglong, Shendong, eastern Inner Mongolia and eastern Ningxia; construction will continue in northern, eastern and central Shaanxi, Yunnan and Guizhou, and will be started in Xinjiang (Peoples Republic of China 2011).

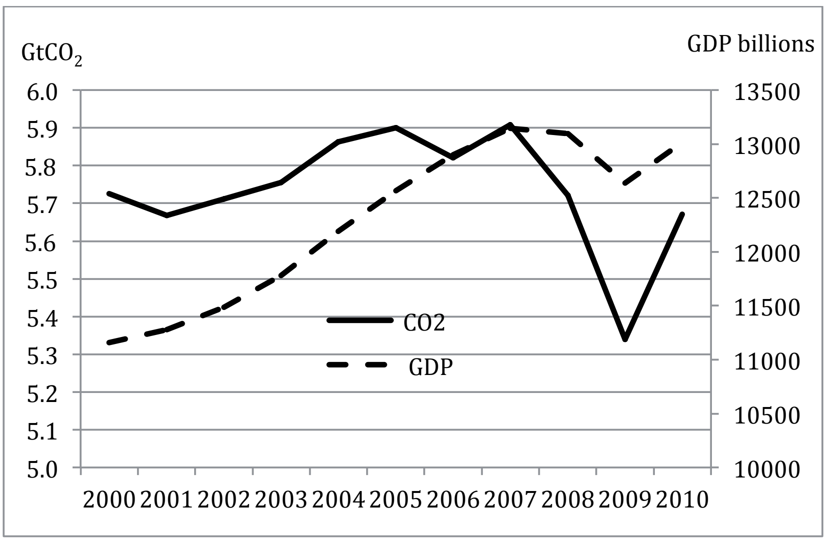
Because of this reliance on coal for economic growth in the interior, Wood Mackenzie (2013) forecast that there will be doubling of coal demand by 2030 and the UHV lines will in fact deliver coal fired electricity from the north-west to the east. Wood Mackenzie says that failure to invest sufficiently in non-coal power sources and efficiency technology could see coal demand increase even further, given that economic growth will not be sacrificed to lower emissions.

Taxing carbon emissions or limiting them by permits that are tradable are efficient methods of greenhouse gas reduction. China is set to adopt emissions trading schemes to cover 700 Mt of CO_2 by 2014 (Climate Bridge 2012). But these will cover only a fraction of the country's emissions (9 Gt in 2010: see *Figure 4*), and even if successful cannot therefore be expected to have an appreciable impact on total emissions in the near term.

4.2 United States

In contrast to China, whose emissions have almost tripled in the period 2000-2010, emissions in the U.S. have declined. Over that period the global financial crisis bit hard; and since then there has been a switch to gas from coal in electricity generation, driven by the price difference between the two fuels.

Figure 5: U.S.: Emissions and GDP, 2000-2010



Sources: WRI (2013); World Bank (2013b).

The national 2010-2020 target for emissions is a reduction of 17% on 2005 levels, pledged by president Obama at the 2010 Cancun United Nations Climate Conference. This is to be achieved by regulation, a national emission trading scheme having failed to pass the senate. The means were fleshed out by the president in his Action Plan (The White House 2013).

Coal fired plants are now subject to very strict emissions standards, there will be higher fuel economy and energy efficiency standards, reductions in fugitive methane emissions, increased adoption of the renewable sources wind and solar and a phase out of fossil fuel subsidies. These measures complement the renewable energy targets that are increasing the adoption rate of renewables in most states. Emission trading schemes in California and north-eastern states cover only a small fraction of national emissions, however, and will exert a limited influence on total emissions.

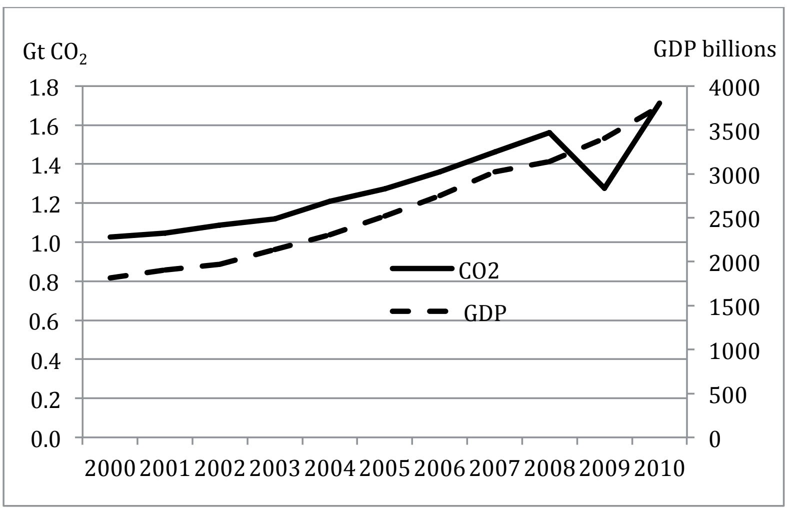
4.3 India

India will suffer greatly as a result of temperature rises above 2°C. Its agriculture, both irrigated and rain-fed, will be severely affected and yet food production will need to increase steadily at the same time to cater for rapid population increase (Hunt 2011). The country therefore has much to gain from an effective global greenhouse gas mitigation strategy.

The size of country's economy more than doubled between 2000 and 2010, while the growth in emissions was somewhat slower as a result of renewable energy capacity. This resulted in a modest improvement in emissions intensity, which is already much lower than that of China and Russia. Its pathway to a low carbon economy would therefore seem to be relatively easy, but there are major impediments to change. As for China, the U.S. and Russia an impediment to rapid change is the existence of long-term power generation; Indian infrastructure locks in 60% of all emissions for the next 20 years (IEA 2013).

Nevertheless, India has pledged to reduce its emission intensity by 20-25% by 2020 from 2005 levels (Ministry of Environment and Forests 2010). A key element in this plan is its Perform Achieve and Trade mandatory trading system for eight energy intensive sectors, including thermal power plants. At the same time India is investing in nuclear power and renewables (Climate Development and Knowledge Network 2013).

Figure 6: India: Emissions and GDP, 2000-2010



Sources: WRI (2013), World Bank (2013b).

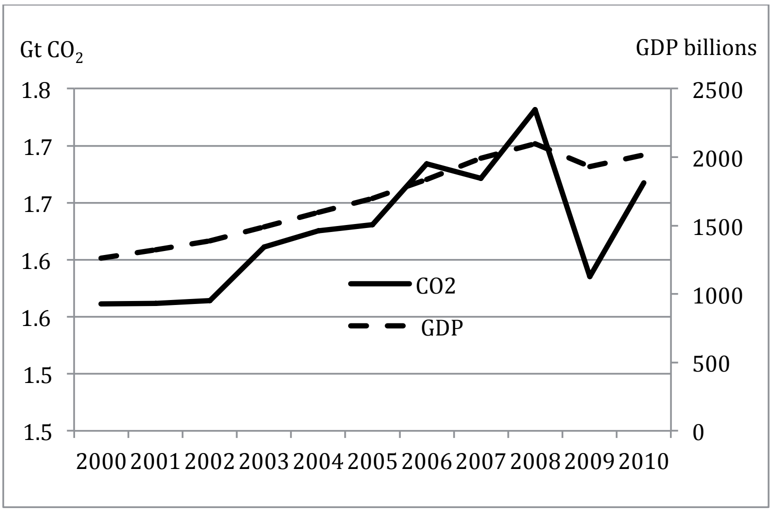
4.4 Russian Federation

Russia has enormous fossil fuel reserves and is now a major user and exporter of gas. Vast domestic energy supply, cold climate and inefficient technologies have ensured that high energy intensity remains endemic to every sector of the economy (U.S. Department of Energy 2012).

By far the most inefficient of the four countries, in terms of emissions intensity of its economy in 2000, Russia has, however, improved somewhat since 2000 and is now more efficient than China.

The large involuntary leakages from its gas distribution network and incomplete combustion by flaring at remote wells make it the world's largest emitter of the powerful greenhouse gas methane. Reducing these emissions together with fossil fuel subsidy reform and an increase in natural gas tariffs will improve emissions intensity in the future (IEA 2013). But there are doubts about how effective Russia's efforts to reduce emission will be, given the hiatus that has characterised Russia's climate policy (RTTC 2013). Moreover, Russia's range of greenhouse gas emission reductions depend on appropriate accounting of the contribution of Russian forests in emissions reduction; in addition, all major emitters need to comply with the legally binding obligations (PBL Netherlands Environmental Assessment Agency 2012).

Figure 7: Russia: Emissions and GDP, 2000-2010



Sources: WRI (2013), World Bank (2013b).

V. FOUR COUNTRY POLICIES TO 2020

In this section a comparison of the challenge faced by each of the four countries is facilitated by comparing their emission intensity paths to 2050. The emission intensity of each of China and India is projected to 2020 according to official policy. In the case of China the emission intensity policy announced covers only the period 2011 to 2015 and an assumption is made that the rate of reduction for this period stays constant to 2020. In the case of India, the mid-point of its pledge of a reduction in intensity of 20%-25% is modelled. In the case of the U.S the rate of reduction in emission intensity achieved in recent years is assumed to continue to 2020; while in Russia the mid-range (20%) of the steep reduction in emissions pledged (UNFCCC 2013b) is set against a forecast increase in rate of economic growth of 4.8% to 2020 – a rate achieved between 2000 and 2010.

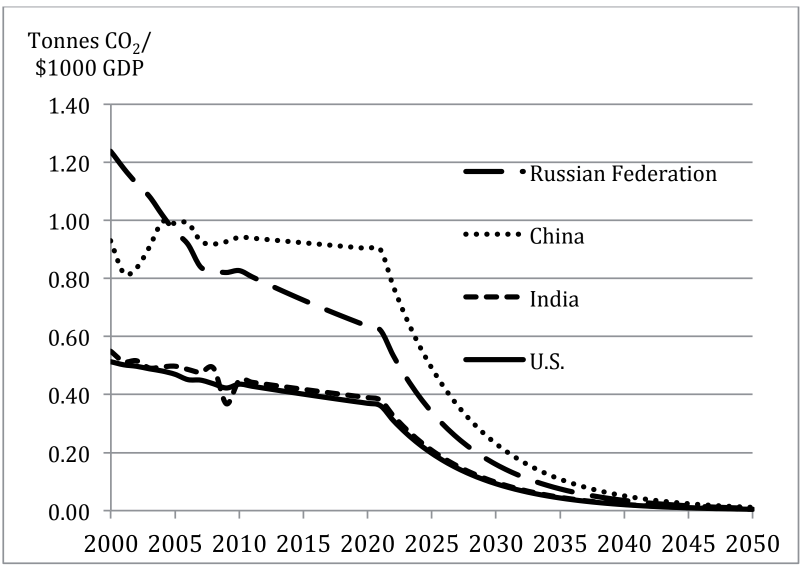
An international climate agreement if foreshadowed for 2020. For illustrative purposes the assumption is made that all countries adopt policies that will enable the world to stay within the carbon budget by 2050. However, to reflect lead time, these policies are assumed to come into effect in 2022.

The rate of reduction in emission intensity to 2022 varies between countries mainly with respect to the baseline chosen. For example the rate of reduction by China is relatively slow because its baseline for reductions is 2011, the soft target being dictated by the strong correlation between economic growth and quantity of emissions, as mentioned earlier.

Russian emissions were very much higher in 1990 than they are now, which means that emissions can grow by 23% by 2020 under its pledge to reduce by 20% on 1990 levels. Nevertheless an improvement in emission intensity is still achieved because economic growth is more rapid than emissions growth.

The rate of decarbonisation required by countries to stay within budget after 2022 is constant. In the case of China and Russia that rate applies to very high rates of emission intensity in 2022; hence the very steep reductions necessary for those countries between 2022 and 2050.

Figure 8: Four Countries: Forecasts in Trends in Emission Intensity to stay within Budget, taking account of Policies to 2020



Sources WRI (2013); World Bank (2013b).

V1. CONCLUSIONS

The need for early action on climate change is illustrated in *Figure 2* where a delay of just 5 years has a marked impact on the rate of emissions intensity required. The postponement of concerted international decision-making to 2020 means that the rate of reduction in emissions will need to be very rapid compared with what has been achieved. As we have seen during the global financial crisis, climate change policies take second fiddle to the maintenance of economic growth (IEA 2013). It is inconceivable that the rates of decarbonisation, required under an effective international agreement, of countries that are coming off high levels of emissions intensity – such as China and Russia, would not slow their economic growth rates.

The Grantham Institute (2013) has done the maths and highlights the risks in investing in fossil fuel companies given the likely collapse in demand for their products if the world embarks on low carbon trajectory. A contrary argument is that the downward pressure on the prices of fossil fuel stocks will be dictated not by the requirements of the carbon budget to avoid catastrophic climate change but by the level of decarbonisation countries are willing to adopt and any reduction in the level of use of fossil fuels that might entail.

But what are the prospects that a comprehensive internationally binding agreement can be struck in 2020? Despite the promise of "fresh universal, legal agreement to deal with climate change beyond 2020" (UNFCCCa:1), countries cannot be forced to adopt binding targets and the non-participation of only one or two large emitters will destroy the overall target's integrity. Moreover, as for the Kyoto agreement, sanctions will not be possible against non-participatory countries or countries that withdraw from an agreement. That the practical barriers to a good binding agreement remain as strong as they were in Copenhagen was emphasised by Garnaut (2012).

Markets, rather than international agreements, are likely to be the main drivers of decarbonisation. We have seen how the relative prices changes of fossil fuels in the U.S. spurred a rapid transition from coal to gas in electricity generation. The official policies of the four countries include the projected contributions of renewable energy. A fairly recent trend, however, and one difficult to take into account is the potential for the accelerating rate of exit from fossil fuel dependence due to falling price of wind and particular solar energy compared with coal (EIA 2013). Off-grid solar would seem to have vast potential in India and Russia. However, the rapid deployment of large solar thermal installations that generate base-load power, and are relevant to China, India and the U.S. will need considerable entrepreneurial and financial inputs; see for example Seba (2010).

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