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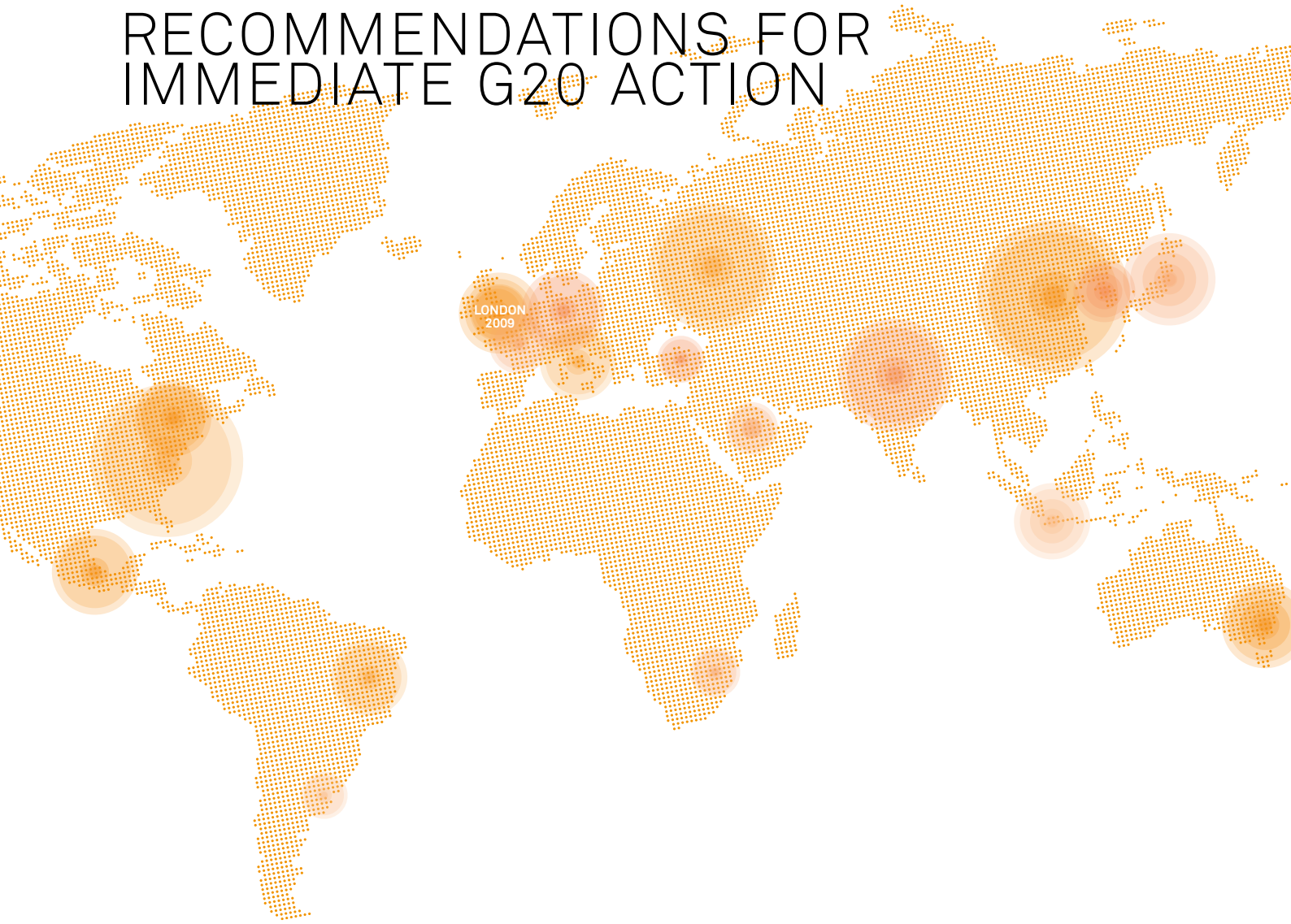
TOWARDS A GLOBAL GREEN RECOVERY

RECOMMENDATIONS FOR IMMEDIATE G20 ACTION



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THE POTSDAM INSTITUTE FOR CLIMATE IMPACT RESEARCH (PIK)
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was established in 2008 at the London School of Economics and Political Science. The Institute brings together international expertise on economics, as well as finance, geography, the environment, international development and political economy to establish a world-leading centre for policy relevant research, teaching and training in climate change and the environment. It is funded by the Grantham Foundation for the Protection of the Environment.

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SUMMARY

The world is facing its worst economic crisis in many decades, caused by massive strains in the global financial system, falling asset prices and a sharp drop in wealth and aggregate demand. To re-start growth, ambitious fiscal stimulus measures have been announced in most G20 member countries and further measures are under consideration. The need for a substantial fiscal boost in the short term provides a great opportunity to undertake projects with a high social return, at a time when inputs are relatively cheap and underutilised resources and workers are available. But additional measures should be timely, well targeted, and taken within a clear long-term framework if they are to help lay the foundations of sustainable growth in the medium and long term without threatening fiscal sustainability when recovery comes.

Public spending aimed at stimulating private investments that help reducing greenhouse gas emissions can perform very well against these criteria for an effective stimulus, while providing the additional benefits of lower energy costs and increased energy security. By focusing on correcting well-known market failures in energy use and R&D, it can avoid crowding out private-sector activity. In fact, green recovery programmes have the potential to stimulate private investment in low-carbon technologies, thereby developing new opportunities for employment, innovation, and wealth creation.

G20 member countries' participation in the fight against both the global recession and climate change is essential. They represent at least three quarters of global GDP, energy consumption and carbon emissions. They have the human and financial resources to push technological boundaries, creating positive spill-over effects and synergies. The present report highlights key measures that G20 members can take to tackle the economic crisis and re-orient development towards sustainable, low-carbon growth. We recommend G20 nations focus their recovery programmes on the following seven strategic areas:

INCREASING ENERGY EFFICIENCY G20 members should initiate and extend programmes that provide loans to home-owners and small and medium-sized enterprises for boosting energy efficiency in buildings. They should strengthen information campaigns about energy efficiency and apply and enforce more stringent standards of energy efficiency to appliances. In the transport sector, introducing fuel efficiency standards, restructuring vehicle taxation, encouraging modal shift, improving urban planning and supporting electrification would ensure that energy is used more efficiently.

UPGRADING PHYSICAL INFRASTRUCTURE G20 members should undertake investments in electricity grid upgrades and extensions, public transportation, integrated freight transport systems and CO_2 pipelines for carbon capture and storage projects. Existing international forums and treaties can be used to encourage additional co-financing and technology transfer for trans-boundary pipelines and electricity grids. G20 members should ensure that new infrastructure investments are 'climate proof', to counter those impacts of climate change to which the world is now committed. G20 members should avoid the

additional risks that would be incurred by investing in infrastructure that locks economies into high-carbon paths.

SUPPORTING CLEAN TECHNOLOGY MARKETS Given the strains in private credit markets due to heightened uncertainty, risk aversion and capital shortages among financial institutions, G20 members should facilitate the financing of clean-technology projects by providing and expanding feed-in tariffs, renewable portfolio standards, production tax credits, guarantees and loans. They should review and refine national procurement guidelines with the aim of going 'carbon neutral', evaluate the possibility of significantly expanding the Clean Technology Fund and the Strategic Climate Fund and aim to dismantle trade barriers affecting clean energy technologies and services.

INITIATING FLAGSHIP PROJECTS G20 members should initiate large-scale demonstration projects for carbon capture and storage (CCS), concentrated solar power, liquids and synthetic gases from ligno-cellulosic biomass, power storage and integrated hydrogen systems, and establish research communities to support such projects jointly, sharing the associated costs and benefits.

ENHANCING INTERNATIONAL RESEARCH AND DEVELOPMENT G20 members should at least triple their total spending on R&D related to energy efficiency, renewables, and CCS. They should establish publicly financed venture capital funds that target innovative clean-energy technologies and develop a G20 Strategic Energy Technology Plan.

INCENTIVISING INVESTMENT G20 members should provide a strong commitment to pricing carbon across all sectors and regions in order to trigger follow-up investments by the private sector and strengthen incentives to invest in technologies and processes that lock in low-carbon production.

CO-ORDINATING G20 EFFORTS G20 members should reaffirm their commitment to an open trading system and refrain from discriminatory provisions in national stimulus packages. Specialised 'Energy & Climate Sherpas' should be appointed to co-ordinate follow-up meetings and fill gaps in existing knowledge.

The main message of this report is one of confidence. Confidence that G20 members will shape an opportunity out of the current crisis. Once economic recovery is under way, markets have to deliver a different quality of growth that is more sustainable – a return to past production patterns is economically neither wise nor desirable. A global green recovery can deliver immediate and long-term economic benefits, cut the risk of dangerous climate change, reduce energy insecurity and competition for natural resources, and prepare the ground for a successful post-Kyoto agreement in Copenhagen in December 2009.

1 INTRODUCTION

The Leaders of the Group of Twenty (G20) advanced and emerging nations gathering in London will rightly focus on ensuring that a global recession does not turn into a global depression. But, as the UK Government has highlighted ahead of the Summit, the environmental implications of the fiscal measures taken by G20 leaders need to be considered. Ensuring that national recovery programmes are 'green' makes sense not only because climate change poses a far more serious threat to the global economy in the long term than do temporary economic downturns. It makes sense because otherwise, once the world economy recovers, sharply increasing energy prices are likely at some stage to trigger subsequent slowdowns. Without the transition towards a low-carbon global energy system, the next economic crisis is pre-programmed. 'Green' recovery programmes are not only an option for sound and effective crisis relief; they are a precondition.

Encompassing countries that account for roughly two thirds of the world's population and three quarters of global gross national product, energy consumption and carbon emissions (see Table 1), the G20 is critical to tackling the global twin economic and climate crises. As emphasised by the United Nations Environmental Programme in its call for a 'Global Green New Deal' (UNEP, 2009), the G20 is the key arena for promoting international action for a global green recovery.

The need for a substantial fiscal boost in the short term provides a great opportunity to undertake projects with a high social return, at a time when inputs are relatively cheap and underutilised resources and workers are available. But additional measures should be timely and well targeted if they are to help lay the foundations of sustainable growth in the medium and long term without threatening fiscal sustainability when recovery comes. Public spending aimed at reducing greenhouse gas emissions can perform very well against these criteria for an effective stimulus, while providing the additional benefits of lower energy costs and increased energy security. By focusing on correcting well-known market failures in R&D and energy use, it can avoid crowding out private-sector activity.

Governments should structure their approach towards a global green recovery in two phases. The first phase includes three measures that would boost aggregate demand and employment in the short term. Governments should focus on **1** improving energy efficiency, **2** upgrading the physical infrastructure of the economy to make it low-carbon, and **3** supporting clean-technology markets. The second phase focuses more on the medium term and comprises **4** initiating flagship projects, **5** enhancing international research and development and **6** incentivise investment for low-carbon growth. Medium-term measures should provide the private sector with incentives to invest more resources in developing the markets that will underpin future growth. They can strengthen investor confidence now and provide the basis for sustained productivity growth in the future. Finally, **7** co-ordinating G20 efforts supports the effectiveness of all the other measures.

Section 2 of this report outlines the challenges of the double economic and climate crisis. Section 3 sets out the rationale for a green stimulus that addresses both short-term economic decline and the challenge of realising the world economy's long-term growth potential. Section 4 presents seven key areas for G20 action towards a global green recovery. The concluding Section 5 briefly highlights the current outlook.

2 THE DOUBLE CRISIS

2.1 THE ECONOMIC CRISIS

Long before the current economic crisis started to materialise, observers had expressed their concerns about 'global imbalances', illustrated by the considerable current account surpluses and increases in foreign exchange reserves in some countries and persistent large current account deficits in the USA, which reached more than US$ 750 billion (almost 6% of GDP) in 2006 (BEA, 2009). There is now a growing consensus that these imbalances, in combination with the monetary policy stances taken around the world, played a major part in the formation of unsustainable price increases – 'bubbles' – in the housing market and provided extra incentives for banks to exploit loopholes in regulatory standards. The result was an opaque redistribution of risks around the globe and serious vulnerabilities in the financial system due to excessive leverage.

After the housing bubbles burst, banks and other financial institutions found themselves with unexpectedly bad loans and impossible-to-value complex financial instruments on their balance sheets and started to reduce their debt burdens and unwind their lending. The credit crunch has been accompanied by efforts by households to increase their saving. Drops in stock market valuations and house prices have greatly reduced wealth for many of them. The Asian Development Bank (ADB, 2009) estimates that financial assets around the world may have fallen in value by more than US$ 50 trillion during 2008, a loss equivalent to almost a year's worth of world economic output. Households are shifting from consumption towards additional saving to make up for the loss of wealth. Furthermore, highly uncertain prospects mean that decisions by consumers and investors to spend have been put on hold in order to reduce risk and keep options open until the uncertainty is resolved. Finally, due to the crisis' origins in the financial system, lending from banks (particularly across borders) has slowed sharply and investors are facing considerable problems gaining access to credit to finance their investment. All of these factors have led to a significant drop in aggregate demand in many industrial countries and entail the risk of a prolonged recession.

Under normal circumstances, if a single country is affected by an economic crisis due to inadequate aggregate demand, a depreciation of the currency brought about by expansionary monetary policy can increase export volumes, dampening some of the initial fall in demand, as increases in trading partners' demand partly compensates. However, the crisis the world is currently facing is truly global; as all countries are affected, there simply is no 'consumer of last resort' that could help other countries in exporting their way out of the crisis. This situation could worsen still further if investment and consumer purchases are put off for longer, sparking a vicious cycle of falling demand, investment, innovation and employment, accompanied by steadily increasing global overcapacity, credit defaults and stock market devaluation.

According to the IMF (2009b), US GDP contracted by almost 1% and euro-area GDP by 1.25% in the fourth quarter of 2008 (i.e. 4% and 5% on an annualised basis). In 2009, their output is forecast to shrink by 1.6% and 1.8% respectively. While the IMF forecasts negative growth rates for OECD member states across the board, economic expansion in emerging economies is also projected to slow

down considerably from the high levels experienced in the past decade, to less then 7 % for China and only a bit more than 5 % for India, for example (see Table 1).

A deep and prolonged depression also damages long-term growth prospects through write-offs of capital owned by firms that go bankrupt during the crisis, through workers forgetting professional skills while unemployed or missing out on on-the-job training opportunities, and through the erosion of social capital in countries in which economic hardship inflicts heavy strains on social relations.

TABLE 1
GDP, ENERGY CONSUMPTION AND GHG EMISSIONS OF G20 MEMBERS.

DATA COMPILED FROM
[1] IMF (2008a),
[2] IMF (2009b),
[3] IEA (2007a; 2007b),
[4] WRI (2009)

COUNTRIES	GDP 2008 [1]		GDP GROWTH PROJECTION 2009 [2]	ENERGY CONSUMPTION 2005 [3]		GHG EMISSIONS 2005 [4]	
	TOTAL 2008 US$ bn	SHARE OF GLOBAL (%)	%	PJ/a	SHARE OF GLOBAL (%)	IN Mt CO_2eq	SHARE OF GLOBAL (%)
ARGENTINA	339	0.5	0.0	2.670	0.6	321	0.8
AUSTRALIA	1.069	1.7	-0.2	5.130	1.1	559	1.4
BRAZIL	1.665	2.7	1.8	7.890	1.7	1.028	2.7
CANADA	1.564	2.5	-1.2	10.901	2.3	736	1.9
CHINA	4.222	6.8	6.7	72.183	15.4	7.250	18.7
FRANCE	2.978	4.8	-1.9	11.882	2.5	576	1.5
GERMANY	3.818	6.1	-2.5	14.367	3.1	1.006	2.7
INDIA	1.237	2.0	5.1	22.389	4.8	1.863	4.8
INDONESIA	497	0.8	3.5	7.499	1.6	598	1.5
ITALY	2.399	3.9	-2.1	7.390	1.6	588	1.5
JAPAN	4.844	7.8	-2.6	22.405	4.8	1.383	3.6
MEXICO	1.143	1.8	-0.3	7.356	1.6	641	1.7
RUSSIA	1.779	2.9	-0.7	26.960	5.7	1.992	5.1
SAUDI-ARABIA	528	0.9	0.8	5.941	1.3	390	1.0
SOUTH AFRICA	300	0.5	1.3	5.440	1.2	434	1.1
SOUTH KOREA	953	1.5	-4.0	9.166	2.0	588	1.5
TURKEY	799	1.3	-1.5	3.584	0.8	400	1.0
UNITED KINGDOM	2.787	4.5	-2.8	9.512	2.0	683	2.7
UNITED STATES	14.334	23.1	-1.6	96.523	20.6	7.098	18.3
G20 TOTAL	47.258	76.0		349.188	74.4	28.132	74.6
REST OF WORLD	14.884	24.0		120.271	25.6	10.594	26.4

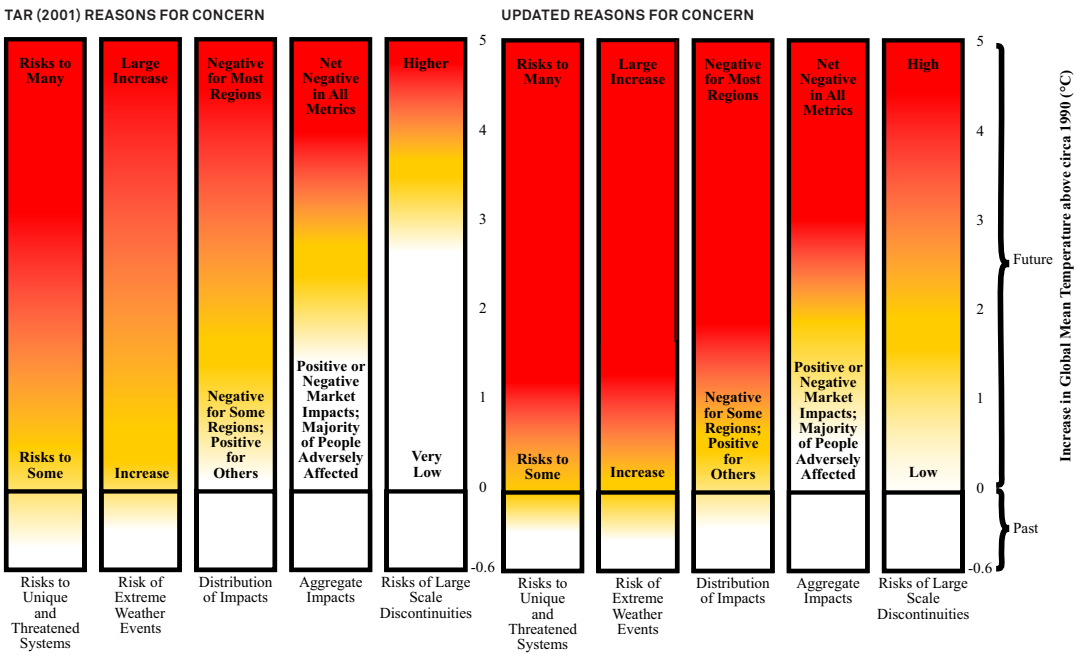
On the macroeconomic front, policy-makers found it difficult over the past decade to tackle the growing imbalances in the global economy, asset markets and financial systems until a global recession materialised. If, similarly, we wait until the more serious climate risks have begun to crystallise before acting, it will be too late to avoid heavy costs, and the challenges to policy-makers will be much greater. The difference is that the costs of unrestrained climate change will be much more profound and longer-lasting than the costs of a temporary economic downturn.

2.2 THE CLIMATE CRISIS

While the world economy is in temporary decline, dangerous climate change poses a permanent and far more serious threat to human development and prosperity. G20 nations account for roughly three quarters of global energy consumption and carbon emissions (Table 1). With rising temperatures, climate change is likely to become unmanageable and catastrophic, pushing the Earth's complex ecology past known and as yet unknown tipping points, which may fundamentally and irreversibly alter the way our planet functions (Lenton et al., 2008). New research indicates that the risks from any given global temperature increase are greater than previously thought (see Figure 1). Scientists also underestimated the difficulty of containing temperature increases. Staying below a 2°C increase – the limit proposed by the European Union – will be challenging because the climate system already contains more warming potential than previously assumed. Greenhouse gas (GHG) emissions are increasing at faster pace (Raupach et al., 2007), the planet's capacity to sequester carbon in natural sinks is decreasing (Canadell et al., 2007) and the temporary cooling effects of aerosols in the atmosphere are likely to diminish as more stringent clean-air policies are applied (Ramanathan and Feng, 2008). Thus the likelihood of global warming in the 21st century even beyond the threshold of a 2.4°C increase is dangerously high (Schellnhuber, 2008).

FIGURE 1
RISKS FROM CLIMATE CHANGE, BY REASON FOR CONCERN, AS APPRAISED BY THE IPCC THIRD ASSESSMENT REPORT OF 2001- COMPARED WITH RECENTLY UPDATED DATA. CLIMATE CHANGE IMPACTS ARE PLOTTED AGAINST INCREASES IN GLOBAL MEAN TEMPERATURE (°C) AFTER 1990

SMITH ET AL. (2009)



Many of factors responsible for higher risks were not yet adequately understood when Stern (2007) concluded that the costs of climate change over the next two centuries, under business as usual, could be similar in magnitude to a loss of 15% of global consumption per head, now and forever. But, as that Review itself made clear, ultimately it is a matter of collective judgement by people around the world what risks they want to run with the planet. Whatever metric is used, those risks are very large if no action is taken.

As with the damages from unrestrained climate change, it is difficult to be precise about the costs of avoiding it. The Intergovernmental Panel on Climate Change (IPCC, 2007) reviewed various estimates, finding that the projected global costs of stabilising GHG concentrations would be between 5.5% and -1% of annual GDP by 2050 (some studies calculate net gains to abatement activities even without factoring in benefits of averted climate change), depending on model assumptions and the stabilisation target (ranging from 445 to 710 ppm CO_2eq). Stern (2007) concluded that to stabilise eventually at 500-550 ppm CO_2eq would cost around 1% of GDP by 2050 (+/- 3%). Some more recent analyses suggest that global cumulative costs of an ambitious low-stabilisation scenario of 400 ppm CO_2eq (after overshooting) could lie below 2.5% of GDP up to 2100 (Knopf et al., 2009). The key conclusion to be drawn from these estimates is that the costs of action are likely to be much less than the costs of inaction[1]. Thus strong and urgent action makes economic sense.

1 Please refer to the Appendix for a detailed discussion of the costs of action and inaction.

3 SHAPING AN OPPORTUNITY OUT OF CRISIS

Providing a stimulus to the economy and protecting the climate do not stand in opposition to each other. Quite to the contrary, well-designed stimulus packages that give priority to spending on 'green' measures designed to avoid carbon emissions can simultaneously help to stabilise aggregate demand in the short run (thus contributing to a quick recovery of the global economy) and yield (potentially large) positive economic returns in the medium and long run by developing the world economy's low-carbon growth potential. Most measures aimed at reducing GHG emissions are related to the improvement of existing capital stocks and development of new technologies.Thus climate change policy can create opportunities for savings to be directed into valuable real capital and wealth formation.

3.1 REVERSING SHORT-TERM DECLINE

In a crisis that is turning out to be the worst since the Great Depression, decisive action to fix the banking system and stimulate demand is needed to return the economy to its potential level of productivity and capacity utilisation. For national governments, there are two ways to correct temporary shortfalls in aggregate demand and stimulate economic activity: monetary and fiscal policies.

Implementing looser monetary policies in the conventional fashion by lowering interest rates provides cheap central bank money to the banking system. This extra liquidity, if passed on to firms and consumers in the form of the expansion of credit, in normal circumstances spurs economic activity. Due to its speedy transmission and relative ease of implementation, monetary policy has been the preferred instrument of macro-economic interventions in recent decades. As a reaction to the crisis, central banks have lowered interest rates considerably, often to historically low levels (e.g. the US Federal Reserve's overnight lending rate now is 0.25%-0.5%, while the European Central Bank has set its rate to 1.5% and the Bank of England to 0.5%, the lowest rate in its long history). But these cuts have not been sufficient to contain the crisis and restore growth. Given the low level of interest rates, there is little leeway for further reductions. More unconventional means of loosening monetary policies, such as the quantitative easing[2] under way in some countries, can still be used when interest rates are near zero, but they are not as well-understood as interest rate policies and their impact is uncertain. An additional, at least as important, question is how effective monetary policy will turn out to be in the face of the banking crisis. Given the huge uncertainties in the market and the need to conserve capital, banks have greatly reduced their lending activities. Credit spreads[3] on all types of risky assets have risen dramatically. Further, investment to expand productive capacity is inhibited by current perceptions of overcapacity and falling prices. This development greatly undermines the effectiveness of the banking system as a transmission channel for monetary policy.

2 i.e. central banks buying assets from the private sector, expanding their balance sheets
3 i.e. the extra interest margin paid compared with that paid on relatively secure government bonds

As a consequence, there is a widespread agreement that the use of fiscal measures as well as monetary policies is required. G20 leaders have recognised this need in the call for "fiscal measures to stimulate domestic demand to rapid effect, as appropriate, while maintaining a policy framework conducive to fiscal sustainability" included in the declaration following the G20 meeting of 15 November 2008 in Washington (G20, 2008, p.2). IMF experts have recommended employing large amounts of public spending, financed by government borrowing, to counter the economic crisis (Spilimbergo et al., 2008), and, in December 2008, the IMF's managing director suggested that a fiscal stimulus exceeding 2% of world GDP would constitute an appropriate response to the current downturn (IMF, 2008b). Despite announced fiscal stimulus packages, growth forecasts have subsequently been considerably revised downwards. The IMF (2009b) reduced its global growth forecast from November 2008 by 1.75 percentage points to minus 0.5%, while HSBC (King and Green, 2009) projects global economic activity to contract by as much as 1.4% in 2009. These figures suggest that even larger fiscal stimulus packages than previously expected will be necessary. A good case can be made for a stimulus of at least 4% of world GDP over the next 12 to 18 months – corresponding to a figure of more than US$ 2 trillion (Bowen et al., 2009).

Table 2 and Figure 2 present an overview of announced G20 stimulus packages; further announcements are expected in many countries as government budgets are reviewed during 2009. In interpreting these figures, it should be kept in mind that some countries – especially in Europe – have adopted smaller stimulus packages because of the assumed size of automatic fiscal stabilisers (such as unemployment and social security benefits) that kick in during periods of recession.

FIGURE 2
FISCAL STIMULUS MEASURES BY G20 MEMBERS

PRASAD AND SORKIN (2009)

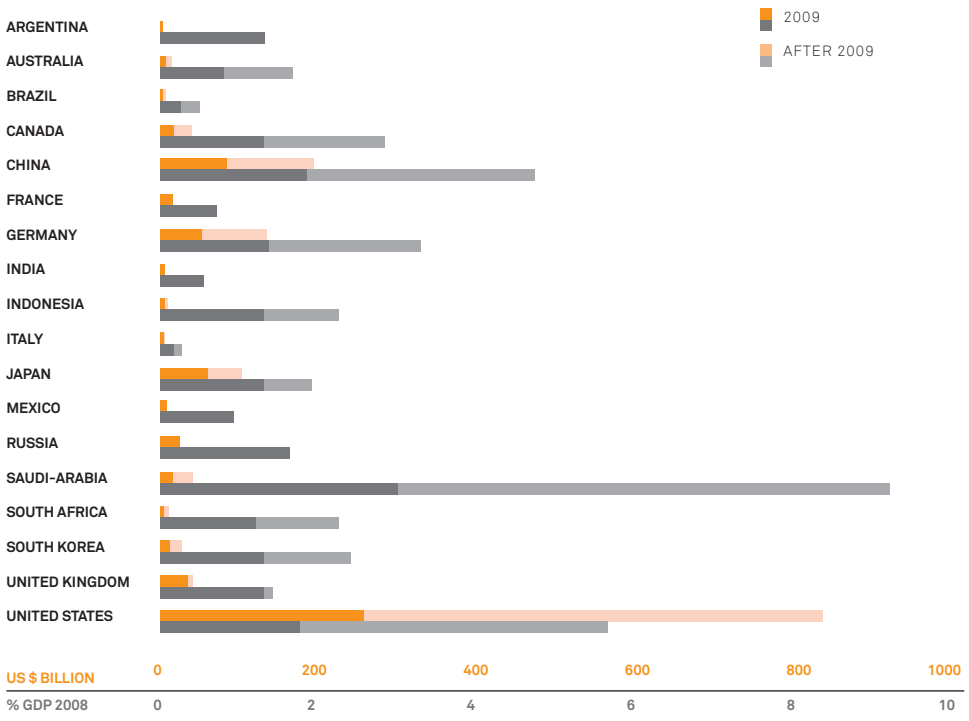


TABLE 2
FISCAL STIMULUS MEASURES IN G20 COUNTRIES

PRASAD AND SORKIN (2009)

COUNTRIES	FUND 2009		FUND AFTER 2009		TOTAL FUND	
	2008 US$ bn	%of GDP	2008 US$ bn	% of year 2008 GDP	2008 US$ bn	% of year 2008
ARGENTINA	4.4	1.3	0.0	0.0	4.4	1.3
AUSTRALIA	8.5	0.8	10.8	1.0	19.3	1.8
BRAZIL	5.1	0.3	3.5	0.2	8.6	0.5
CANADA	23.2	1.5	20.4	1.3	43.6	2.8
CHINA	90.1	2.1	114.2	2.7	204.3	4.8
FRANCE	20.5	0.7	0.0	0.0	20.5	0.7
GERMANY	55.8	1.5	74.6	2.0	130.4	3.4
INDIA	6.5	0.5	0.0	0.0	6.5	0.5
INDONESIA	6.7	1.3	5.8	1.2	12.5	2.5
ITALY	4.7	0.2	2.3	0.1	7.0	0.3
JAPAN	66.1	1.4	38.3	0.8	104.4	2.2
MEXICO	11.4	1.0	0.0	0.0	11.4	1.0
RUSSIA	30.0	1.7	0.0	0.0	30.0	1.7
SAUDI-ARABIA	17.6	3.3	32.0	6.1	49.6	9.4
SOUTH AFRICA	4.0	1.3	3.9	1.3	7.9	2.6
SOUTH KOREA	13.7	1.4	12.4	1.3	26.1	2.7
UNITED KINGDOM	37.9	1.4	2.9	0.1	40.8	1.5
UNITED STATES	268.0	1.9	573.2	4.0	841.2	5.9
G20	674.2	1.4	894.3	1.9	1568.5	3.3

Prasad and Sorkin (2009), drawing on IMF estimates, present data on the size of new measures in fiscal stimulus packages. These numbers differ from official announcements by national governments, as the latter typically include some measures that had already been designed before the full extent of the crisis became clear. For many countries, the size of the packages is substantial, amounting to US$ 841.2 billion in the US (5.9% of GDP), US$ 204.3 billion in China (4.8% of GDP), and US$ 104.4 billion in Japan (2.2% of GDP). Adding up to an overall amount of US$ 1.6 trillion, this corresponds to 3.3% of the combined GDP of those G20 members for which data are available.[4] The timing of planned spending varies, but is generally spread over two or three years. On average, funds of roughly US$ 670 billion (i.e. 1.4% of the G20 members' combined GDP) will be made available in 2009, and about US$ 890 billion (corresponding to 1.9% of GDP) in 2010 or later (Table 2). How stimulus measures are to be implemented varies across countries. On average, one third is to be implemented through tax cuts and the remaining two thirds through fiscal spending. Given the estimates of the size of the discretionary measures that have already been proposed, there is room for the G20 as a whole to take further action.

4 Data on fiscal stimulus measures are reported for all G20 members except for Turkey.

However, a number of developing G20 countries have dedicated only small amounts toward fiscal stabilisation measures. For example, Argentina, Brazil, India, Indonesia, and Mexico have passed plans to spend US$ 4.4 billion, US$ 8.6 billion, US$ 6.5 billion, US$ 12.5 billion and US$ 11.4 billion respectively. This is especially worrisome as inflows of foreign direct investment (FDI), which constitute an important source of finance for a large number of developing countries, are starting to fall or reverse. According to figures by the United Conference on Trade and Development (UNCTAD, 2009), the annual growth rate of FDI inflows to developing countries was still positive but dropped to 4% in 2008, after more than 20% in 2007. If the crisis worsens still further, the likely decrease in FDI inflows would create serious vulnerabilities for developing countries' financial systems. Co-ordinated global fiscal stimulus packages should take this fact into account and ensure that some of the additional investment that they generate benefits the developing countries most vulnerable to the slowdown in global financial flows.

3.2 PROMOTING LONG-TERM GROWTH

Fiscal policy – supported by accommodatory monetary policy – is the right approach to address current economic challenges. But it can do much more. It could, at the same time, trigger the 'Third Industrial Revolution' many have long called for. Failure to seize this opportunity will mean that resources will be squandered, further cementing our economies' carbon dependence and leaving behind enormous financial and environmental debts for future generations to pay off. The need for a substantial fiscal boost in the short term provides a great opportunity to undertake projects with a high social return, at a time when inputs are relatively cheap and underutilised resources and workers are available. The challenge of stopping climate change opens up new opportunities for investment and wealth creation, and hence also for savers.

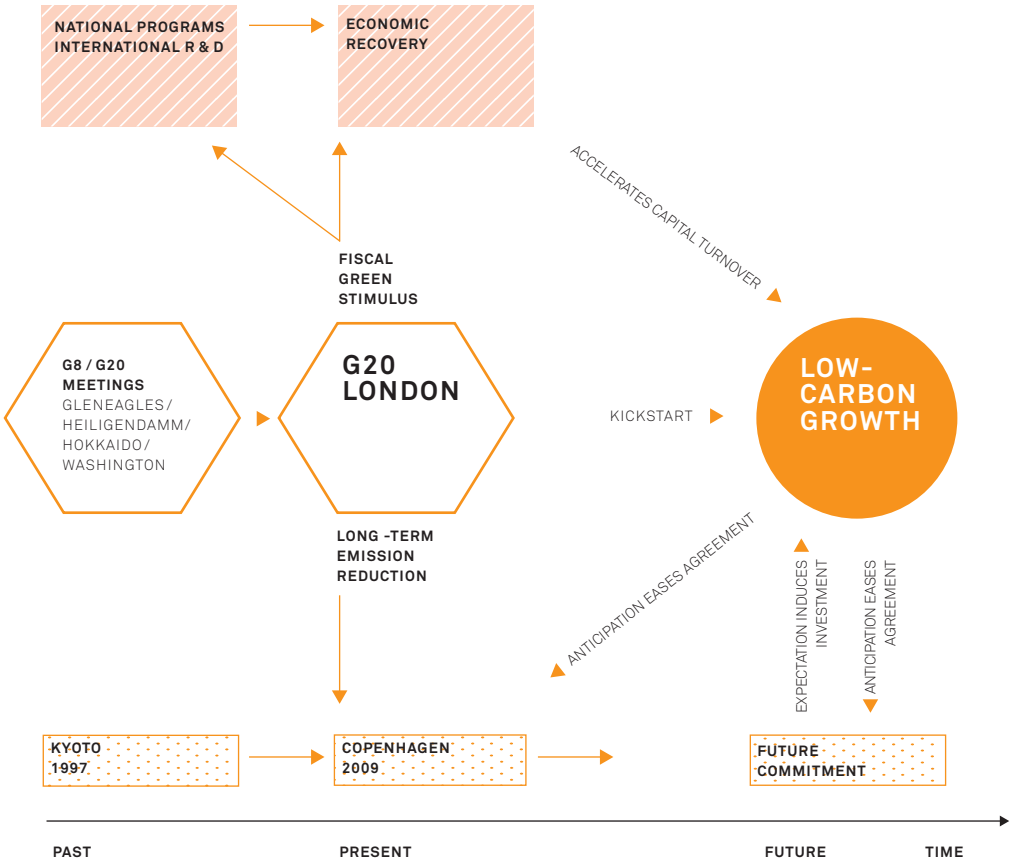
World economic growth is likely to benefit from limiting global warming over the long run because the costs of acting on climate change are expected to be much lower than the costs of inaction. It is not a question of whether or not to act on global warming. Nor is there doubt about timing, because preliminary results of modelling exercises suggest that delaying action would sharply increase the cost of subsequent action[5]. To keep costs down, a broad agreement on the scale and pace of emissions reductions, and on cost-effective institutions and instruments to achieve them, needs to be implemented as soon as possible. In other words, cost-efficient action urgently requires a Global Deal on Climate Change, as outlined by LSE's Grantham Research Institute, PIK and the European Commission.[6] The key elements of a Global Deal on Climate Change comprise:

- *the establishment of a global carbon market*
- *technology co-operation and sharing*
- *action to slow deforestation*
- *funds to assist adaptation to residual climate change in developing countries*

Such an agreement will be the objective of the upcoming United Nations Framework Convention on Climate Change (UNFCCC) conference in Copenhagen in December 2009. Given that past negotiations have made little progress, any vehicle that could facilitate the process towards reaching a successful post-Kyoto agreement in Copenhagen is desirable. The fiscal packages currently being prepared and reviewed by G20 nations represent such a vehicle. Fiscal spending on the decarbonisation of the energy system would lower the cost of reaching given reduction targets and hence facilitate their agreement. Figure 3 puts the G20 London Summit and the UNFCCC Copenhagen Summit into perspective. Both events sit within a context of mutually reinforcing objectives. A fiscal green stimulus induces short-term recovery while also developing the economy's low-carbon growth potential. The anticipation of low-carbon growth facilitates efforts to reach an agreement in Copenhagen.

5 Together with Fondazione Eni Enrico Mattei (FEEM) and Centre International pour l'Environnement et le Développement (CIRED), PIK is currently conducting an in-depth comparison of energy-economy models (RECIPE - Report on Energy and Climate Policies in Europe) to assess global mitigation options and costs on regional and sectoral levels. First results will be made available in May 2009.
6 Stern et al. (2008) ; Edenhofer et al. (2008) ; EC (2009)

FIGURE 3
THE G20 LONDON SUMMIT AS A GATE-KEEPER FOR SHORT-TERM RECOVERY AND LONG-TERM GROWTH



Over recent months, various contributions have highlighted the merits of 'greening' fiscal stimuli [7]. Though they differ in geographical scope and sectoral detail, they all share a common argument: capital- and labour-intensive initiatives (such as enhancing energy efficiency in buildings and appliances, upgrading power grids, developing renewable energy sources, building demonstration plants for carbon capture and storage and extending public transportation) will create jobs, increase energy security and help to head off dangerous climate change. G20 leaders now have the opportunity to pave the way towards a successful Copenhagen agreement by greening their fiscal spending and jointly developing the world economy's low-carbon growth potential.

7 New Economics Foundation (2008); Pollin et al. (2008); Bowen et al. (2009); UNEP (2009); Houser et al. (2009); Mabey (2009)

3.3 CRITERIA AND INSTRUMENTS

In the current discussion, it is often emphasised that stimulus measures have to be timely, targeted and time-limited in order to achieve maximum impact without generating adverse lock-in effects or crowding out private spending in the recovery. Many of the investments proposed here will automatically cease once the associated capital stock (such as an electricity grid) is completed. But some measures (e.g. support for R&D or renewable energies) will need to be provided with new sources of funding (from tax revenues or private sources) as deficit financing is reined in, and will need to extend beyond the current slowdown, because they address market failures that will remain when the economy recovers. Moreover, green fiscal measures not only have to stimulate economic activity but also help to avoid dangerous climate change.

Hence, we suggest that any proposed policy has to meet the following criteria to qualify as part of an effective green stimulus:

- *Speed is a crucial issue, as only measures that can be decided and implemented relatively quickly can take effect in time to slow down and reverse the current downward trend of economic growth*
- *In the same vein, a measure will have a higher potential to contain the looming recession if it triggers additional spending from the private sector, i.e. if the associated multiplier effect is large*
- *Besides being timely and having a large multiplier effect, green fiscal stimulus measures should facilitate the transition towards sustainable growth in a low-carbon economy and result in long-term climate benefits, such as reducing future energy consumption and contributing to the decarbonisation of the energy system*

Green recovery measures promise to be superior to deficit-financed spending on consumption from a public finance perspective, because tax-payers implicitly receive compensation for higher future taxes in the form of decreased expenses on energy and lower costs of abating GHG emissions.

The following points should also be taken into account when adopting fiscal measures: First, implementation lags (i.e. the time until spending plans are formulated and a measure achieves its desired impact) might be rather long, at least for certain types of public spending. Second, deficit spending increases public debt, which will eventually have to be paid back. Countries which already bear a significant debt burden might also see the perceived risks of default on sovereign debt (and/or of higher inflation in the medium term) increase, thus raising risk premiums and consequently the costs of refinancing their respective debts. Third, public spending can create lock-in effects, in the sense that sunk costs and the creation of vested interests make it hard to phase out certain measures once an immediate crisis has been resolved, which then leads to continued subsidisation of uncompetitive activities.

In order to direct funds to those economic activities where they are most urgently needed and that contribute most to a green economic recovery, governments have a number of possible tools at their disposal. As there are large uncertainties about which measures will prove most effective in the current situation, there is a case for adopting diversified packages of fiscal measures:

- *Governments can increase their spending on public procurement, i.e. on items that show up directly on their balance sheets, such as schools, government edifices, public infrastructure, etc. To make such spending part of a green recovery package, priority can be given to measures which bring about climate benefits, such as retrofitting buildings to make them more energy efficient, or investing in public transport (especially when fuelled by low-carbon energy sources) and energy grids.*

- *Across-the-board tax cuts can be implemented relatively quickly and leave higher disposable incomes in the hands of consumers. Given the current climate of uncertainty affecting households, it is likely that a large share of this additional income will be saved and hence will not do much to stimulate demand (however, increased saving might turn out to be a boon for the ailing banking sector).*

- *Given the large amounts of finance required, mobilising private sector investment and engaging in public-private partnerships will be crucial to any successful attempt to tackle the economic crisis. This includes government loan guarantees or (upfront) refundable tax credits targeted at private sector investments in green recovery measures.*

- *Finally, setting appropriate standards and regulations, such as energy efficiency standards for household appliances or vehicle fuel efficiency standards, can induce investment, provided that the appropriate general conditions are in place. However, it is well known that command-and-control measures often result in inefficient outcomes. Therefore, policy-makers should be careful to avoid those inefficiencies when designing standards and regulations and try to meet environmental objectives at the lowest costs by targ eting negative externalities as close as possible to their origin.*

We emphasise that, where public spending is advocated, it should be carried out in the context of a clear long-term framework that will ensure fiscal sustainability as well as sustainable growth over the long term. That entails developing an incentive structure, including carbon pricing, that passes more responsibility for climate-change action to the private sector over time.

4 G 20 ACTION TOWARDS A GLOBAL GREEN RECOVERY

4.1 CURRENT INITIATIVES AT NATIONAL LEVEL

Recognising the need for green measures in recovery programmes, the large majority of G20 recovery packages that have been announced so far include elements of increased spending on some or all of low-carbon power, energy efficiency, R&D, modal shift (i. e. encouraging people to switch from road to rail) as well as waste and water treatment and pollution control (see Table 3 below).

Owing to the complexity of the issue and the multitude of channels through which stabilisation policies and environmental policy interact, it is hard to quantify precisely what the appropriate share of green measures in stabilisation packages would be, but there are some yardsticks to guide policy-makers. Bowen et al. (2009) present a 'ball-park' figure of 20 % of the discretionary fiscal stimuli. That would allow for the diversity in fiscal measures that is advisable given the uncertainty about fiscal multipliers in present circumstances. It would also generate a flow of spending of the same order of magnitude as model results suggest is necessary for investment in emission abatement. With fiscal packages announced so far totalling US $ 1. 6 trillion for G20 member states, the 'ball-park' figure corresponds to more than US $ 300 billion. To put this number in perspective, it is of the same order of magnitude as the US $ 200 – 350 billion per year that, according to McKinsey & Company (2009), are required in additional investment flows to set the world economy on a low-carbon growth path[8] .

While under normal circumstances the lion's share (roughly 80%, according to estimates by UNFCCC, 2008) of required investment is likely to be provided by the private sector, a higher proportion needs to be spent by governments in the near future, while private investment is severely discouraged by the short-term economic outlook. Estimates by UNEP and New Energy Finance (2008) indicate that transactions related to clean-energy projects dropped sharply last year, falling by more than 30% in the first quarter of 2008 compared with the last quarter of 2007 and by a further 15% in the second quarter, lending support to the argument that urgent government action is required to sustain investment.

Table 3 gives an overview of green fiscal measures in G20 countries. The numbers cited, taken from HSBC (Robins et al., 2009), are based on announcements from national governments and finance ministries. They differ from estimates provided by IMF (2009c) analyses, reflecting ambiguities about the additionality and timing of proposed measures[9]. Even the most comprehensive available data on proposed green measures are plagued by serious shortcomings, making additional research highly desirable. The numbers should at best be regarded as an indication of different governments' propensities to spend on green measures and of overall funds available for green spending in the near term.

Given announced fiscal stimulus packages, G20 governments have dedicated roughly 15% of the total to green measures. There are pronounced

8 However, note that most fiscal packages run over several years.
9 Adding up the announced stimulus packages yields a total of US$ 2.6 trillion, in contrast to the IMF estimate of US$ 1.6 trillion summarised in Figure 2. But Robins et al. (2009) estimate that for China, for example, only 30-40% of the government's announced US$ 586.1 billion spending plan will comprise additional funds; for Italy, only US$ 6.5 billion out of an announced US$ 103.5 billion constitute new spending.

TABLE 3
GREEN FISCAL MEASURES IN THE G20

DATA WERE REPORTED FOR ALL G20 MEMBERS EXCEPT BRAZIL, RUSSIA, SOUTH AFRICA AND TURKEY. BASED ON ROBINS ET AL. (2009) AND OWN CALCULATIONS

	TOTAL FUND	GREEN FUND TOTAL	FUND AS SHARE OF 2008 GDP	GREEN SHARE IN TOTAL STIMULUS	GREEN STIMULUS AS AS SHARE OF 2008 GDP	RENEWABLE POWER	CCS/OTHER	BUILDING EE	LO C VEHICLES	RAIL	GRID	WATER/ WASTE	PERIOD (YEARS)
	2008 US$ bn		%	%	%	2008 US$ bn							
ARGENTINA	3.7	0.0	1.1	0.0	0.0	-	-	-	-	-	-	-	2009
AUSTRALIA	26.7	2.5	2.5	9.3	0.2	-	-	2.5	-	-	-	-	2009 - 2012
CANADA	31.8	2.6	2.0	8.3	0.2	-	1.1	0.2	-	0.4	0.8	0.1	2009 - 2013
CHINA	586.1	200.8	13.9	34.3	4.8	-	-	-	1.5	98.7	70.0	30.7	2009 - 2010
FRANCE	33.7	7.1	1.1	21.2	0.2	0.9	-	0.8	-	1.3	4.1	-	2009 - 2010
GERMANY	104.8	13.8	2.7	13.2	0.4	-	-	10.4	0.7	2.8	-	-	2009 - 2010
INDIA	13.7	0.0	1.1	0.0	0.0	-	-	-	-	-	-	-	2009
INDONESIA	5.9	0.1	1.2	1.6	0.0	0.1	-	-	-	-	-	-	2009
ITALY	103.5	1.3	4.3	1.3	0.1	-	-	-	-	1.3	-	-	2009 onwards
JAPAN	485.9	12.4	10.0	2.6	0.3	-	-	12.4	-	-	-	-	2009 onwards
MEXICO	7.7	0.8	0.7	9.7	0.1	-	-	0.8	-	-	-	-	2009
SAUDI-ARABIA	126.8	9.5	24.0	7.5	1.8	-	-	-	-	-	-	9.5	2009
SOUTH KOREA	38.1	30.7	4.0	80.5	3.2	1.8	-	6.2	1.8	7.0	-	13.9	2009 - 2012
UNITED KINGDOM	30.4	2.1	1.1	6.9	0.1	-	-	0.3	1.4	0.4	-	-	2009 - 2012
UNITED STATES	972.0	112.2	6.8	11.5	0.8	32.8	6.6	30.7	4.8	9.9	11.9	15.6	10 Years
EUROPEAN UNION	38.8	22.8	0.2	58.7	0.1	0.6	12.5	2.8	1.9	-	4.9	-	2009 - 2010
G20 (EXCL. EU)	2.609.6	396.0	5.5	15.2	0.8	35.5	7.6	64.3	10.1	121.8	86.8	69.8	

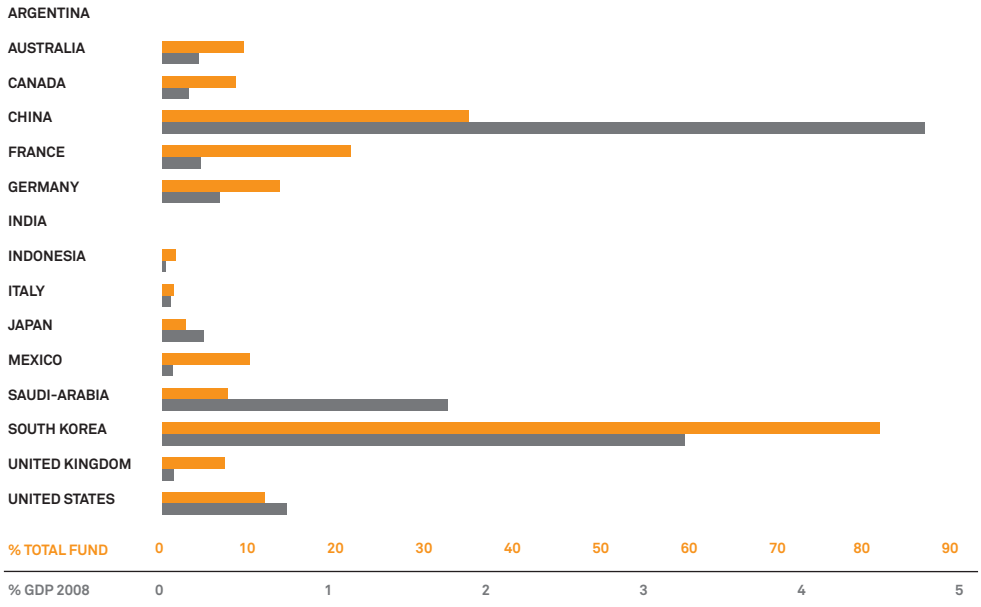
differences across countries. While most countries remain well below the 20% suggested by Bowen et al., South Korea and China will spend as much as 80.5% and 34.3% respectively of their stimulus packages on broadly green measures – 3.2% and 4.8% of total GDP respectively. As in the past some countries have put more emphasis on green measures than others, fiscal stimulus packages are now a good opportunity for the latter countries to close existing gaps in spending on environmental issues.

With regard to sectors relevant to halting climate change, rail transport, electricity grid expansion, building efficiency and (to a lesser extent) support for renewable energies are the main beneficiaries. China's National Development and Reform Commission's stimulus package, for example, includes almost US$ 100 billion for rail infrastructure, and US$ 70 billion for grid expansion. In the USA, the combined amount proposed within the framework of the Emergency Economic Stabilization Act (EESA) and the American Recovery and Reinvestment Plan (ARRP) includes more than US$ 30 billion on both renewables and building energy efficiency.

It is difficult to project accurately the fiscal multiplier effects and the job creation likely to be associated with these measures. Each crisis is different, individual countries are affected in different ways and the effectiveness of fiscal spending depends very much on country-specific conditions. IMF (2009a) staff estimates suggest that investing in infrastructure yields the highest multipliers, ranging from 0.5 to 1.8; many green measures fall in this category. Mapping these estimates of multipliers to areas of green fiscal spending, Robins et al. (2009) estimate a total multiplier effect of just over one.

FIGURE 4
ANNOUNCED GREEN FUNDS AS SHARE OF TOTAL FISCAL PACKAGE AND SHARE OF YEAR 2008 GDP

ROBINS ET AL. (2009)
AND OWN CALCULATIONS



This compares favourably with multipliers for tax cuts, for which the corresponding range is 0.3 to 0.6, and spending on safety nets, transfers to state and local governments, assistance to small and medium enterprises, and support for the housing market, with a range of 0.3 to 1.0 (IMF, 2009a).

Many political leaders have announced ambitious goals for the employment effects of green stimuli. With its green spending of US$ 30.7 billion, South Korea aims to protect more than 700,000 workers from unemployment. In its September 2008 report, the Center for American Progress (Pollin et al., 2008) estimates that a green stimulus of US$ 100 billion could safe roughly 2 million jobs in the USA. These numbers are in line with a recent study by the Peterson Institute for International Economics and the World Resources Institute (Houser et al., 2009), which argues that US$ 1 billion spent on green fiscal measures has the potential to create about 30,000 jobs while saving the US economy US$ 450 million on energy costs and avoiding more than 0.5 Mt of CO_2 emissions.

Fiscal measures taken in the next few quarters can also help to provide the basis for sustaining employment in the longer term. The potential for green jobs in the long run is significant. For example, UNEP (2009) estimates that, globally, more that 10 million jobs in the biofuels industry and more than 3.8 million in the production of highly efficient vehicles are possible in the long term if the world economy is re-directed towards low-carbon growth.

4.2 SEVEN STRATEGIC AREAS FOR G20 ACTION

In tackling the economic crisis, it would be helpful for G20 governments to structure their efforts towards a global green recovery in two phases. The first phase would include three measures aimed at directly boosting aggregate demand and employment in the short term: **1** improving energy efficiency, **2** upgrading the physical infrastructure and **3** supporting clean technology markets. The second phase would focus on the medium term and comprise **4** initiating flagship projects, **5** enhancing international research and development and **6** incentivise investment for low-carbon growth. Medium-term measures should boost investment and demand by providing incentives for the private sector to develop the high-growth markets of the future. They would strengthen economic confidence now and provide the basis for future productivity growth. Finally, **7** co-ordinating G20 efforts would enhance the effectiveness of all other measures, building synergies and lessening competitiveness concerns. As G20 countries account for roughly three quarters of global gross national product, energy consumption and carbon emissions, their combined efforts constitute a critical mass to trigger a global green recovery.

IMPROVE ENERGY EFFICIENCY

Energy efficiency improvements are well-suited for mitigating the current economic crisis. All G20 nations have the potential for substantial energy efficiency improvements, many of which have already been identified in country-specific analyses. Such studies provide valuable guidance as to the most promising technology options on which to concentrate efforts. Some G20 members have already launched related policy programmes, such as the Integrated Energy and Climate Programme (IEKP) in Germany. In all countries, further potential for energy efficiency improvements exists, so these programmes may be scaled up while the downturn lasts, as idle capacity provides the opportunity for accelerated modernisation and replacement.

SPEED Regarding the speed of implementation, public programmes by G20 members can be put into place quickly by providing targeted credit support combined with increased efficiency standards. Planning precisely how to implement these standards can be left to decentralised decision-making by firms and households, avoiding the frictions and inefficiencies of more detailed bureaucratic intervention.

MULTIPLIER Energy efficiency measures are expected to have a high multiplier effect because they are aimed at sectors like construction that are suffering severely from the current demand reduction and where employment is at serious risk. Providing the right incentives for modernisation and early replacement of buildings and appliances can trigger large private investments that would otherwise be put on hold by households and firms. As pointed out by Fuller et al. (2009), investments in energy efficiency are very often cost-efficient even under normal circumstances, but are not undertaken for

various reasons, such as home-owners shying away from large up-front expenditures. Innovative public finance mechanisms and underwriting of new private-sector finance initiatives are ways of remedying this economic inefficiency. In addition, lower spending on energy costs frees up income that can be spent in other sectors of the economy.

LONG-TERM CLIMATE BENEFITS Energy efficiency improvements have a double long-term benefit as they reduce emissions and energy costs simultaneously. Temporarily low energy prices due to the reduction in aggregate demand do not provide sufficiently strong signals to undertake necessary efficiency investments now. Additional instruments such as efficiency standards and targeted subsidies are needed. Otherwise, resurgent energy prices will constrain growth once economies start to recover. In its latest World Energy Outlook (IEA, 2008a), the IEA cautioned that increasing world demand could cause oil prices to rise as high as US$ 200 per barrel by 2030. In a recent interview, the IEA's Executive Director had warned that supply bottlenecks could result in oil prices of up to US$ 200 per barrel already by 2013 (Süddeutsche Zeitung, 2009). Without substantial investments in energy efficiency, resurgent energy prices would impose a serious obstacle to continued growth once economies start to recover. Improvements in energy efficiency allow importing countries to increase their energy security and save on energy costs.[10]

Box 1 on energy efficiency improvements summarises a collection of sector studies of G20 members, focusing on buildings, transport, industrial electricity use and electricity generation. The empirical basis for assessing the scope of private investments that would imply cost-effective energy efficiency improvements is thin. The same is true for the public spending needed to induce these efforts. However, as a rough estimate, it seems reasonable to assume that countries have the capability to realise private investments for energy efficiency improvements in the order of 1% of GDP, of which at least 20% should come from public support (probably more given the current circumstances in financial markets).

For all countries included in the table in Box 1, 'retrofitting' buildings with insulation is a highly promising option to achieve cost-efficient energy savings. Many of these improvements can be expected to be of the 'no-regret' type, as pointed out by the IPCC (2007) in its Fourth Assessment Report, which suggests that, globally, energy used by buildings can be reduced by 29% by 2030 at zero net costs.[10]

▶ We recommend that G20 members grant subsidised loans for building retrofit to homeowners, initiate information campaigns, and apply and enforce energy efficiency standards for buildings and appliances, so that 'no-regret' options in building energy efficiency will indeed be realised.

10 According to several studies performed by McKinsey&Company (McKinsey, 2008), most of the efficiency investments generate an internal rate of return of 10% or higher and should therefore be seen as profitable investment schemes.

In all G20 members, a significant fraction of energy use is in the transport sector. The transport sector is especially hard to decarbonise, because of the limited technological options. Box 1 highlights the potential for energy savings in transport, where cost-efficient energy savings between 18% (UK) and 31% (Germany) by 2030 are realistic options.

▶ We recommend that G20 members increase energy efficiency in the transport sector by adopting fuel efficiency standards, restructuring vehicle taxation based on carbon emissions, encouraging modal shift from road to rail in passenger as well as freight transport, shortening trips through improved urban planning and supporting the move toward electrification of transport.

BOX 1
ENERGY EFFICIENCY IMPROVEMENTS

Improving energy efficiency is a top priority in public policy and research. Numerous studies have highlighted the potential for greater efficiency in various countries and several public programmes target this sector. Most engineering studies start from present conditions and consider the improvements achievable with available technology. They find a large potential for reducing energy consumption that would pay off (given plausible discount rates) even in the absence of climate policies. These options are termed 'no-regret'.

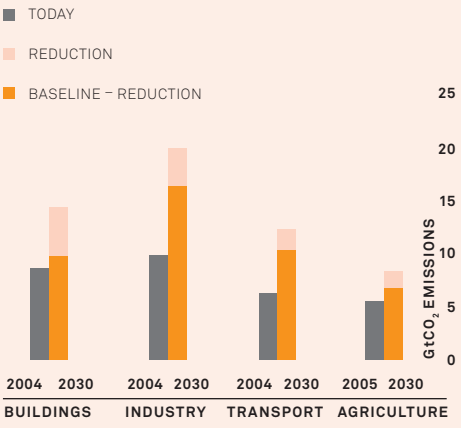


FIGURE
BASELINE EMISSIONS AND REDUCTION POTENTIALS FOR BUILDINGS, INDUSTRY, TRANSPORT, AND AGRICULTURE. BUILDINGS AND INDUSTRY INCLUDE EMISSIONS FROM ELECTRICITY AND HEAT

IPCC (2007) AND IEA (2008b)

Economic studies apply the concept of X-inefficiency, which exists where a given output could be achieved with fewer inputs; see Feijoó et al. (2002). Both strands of literature point to vast potential cost savings. The Figure below presents current emissions, baseline emissions in 2030 and the cost-effective reduction potential for various sectors.

The assessment is based on 'bottom-up' analysis, which limits the scope of investigation to a given set of options. It is therefore reasonable to assume that the estimates are at the lower end of the range of what is possible. Despite this qualification, it remains clear that no-regret options are not sufficient to bring emissions below current levels if baseline emissions continue outpacing efficiency improvements. No-regret options are only the 'low-hanging fruits' that can be plucked to reduce emissions growth. Achieving substantial emission reduction requires more far-reaching changes in the longer term.

For a green recovery programme, we reviewed a number of recent engineering-based studies that consider specific measures and technology solutions for energy savings. In addition,

TABLE
ENERGY SAVING, EMISSION REDUCTIONS, AND INVESTMENT REQUIREMENTS IN SELECTED COUNTRIES. BUILDINGS INCLUDE ELECTRICITY USED BY APPLIANCES.

DATA COMPILED FROM SEVERAL STUDIES. MORE DETAILED ANALYSIS IS AVAILABLE FROM PIK. THE NUMBERS ONLY REFER TO FIRST-ORDER EFFECTS OF ENERGY SAVINGS AND EMISSION REDUCTIONS AND IGNORE ANY SECOND-ORDER EFFECTS SUCH AS 'REBOUND' EFFECTS.

		ENERGY SAVINGS IN 2030		EMISSION REDUCTION IN 2030	ANNUAL INVESTMENTS STARTING TODAY
		% of sector	Peta Joule	$MtCO_2eq$	Billion Dom. Currency
GERMANY	Buildings	33	1400	120	15
	Industry Elec.	24	470	40	3
	Transport	31	850	60	11
	Power Generation	10	330	35	2
UK	Buildings	32	1200	90	
	Industry Elec.	21	250	20	
	Transport	18	400	29	
	Power Generation	5	200	20	
USA	Buildings	28	9000	1100	18
	Industry Elec.	14	650	90	3
	Transport	18	6000	400	21
	Power Generation	8	1500	140	4
JAPAN	Buildings	31	2100	220	7
	Transport	30	1000	71	5
	Power Generation	4	200	20	
INDIA	Buildings	30	4500	450	5
	Industry Elec.	30	1200	120	3
	Transport	28	1400	100	
	Power Generation	26	4300	350	5

these studies provide data on how much investment is needed to achieve energy savings, which can be translated in turn into energy cost savings and GHG emission reductions. The following Table compares immediate gross total investments with longer-term cost-effective energy savings and emission reductions.

The studies cited did not take into account the circumstances of the current economic crisis. Rather, they costed investment as if it crowds out other activities. The issue of overcapacity in the sectors supplying investment goods and services was not the focus of these studies. Moreover, the results are highly sensitive to assumed replacement and modernisation rates. Given these factors, there is room to achieve the longer-term efficiency improvements earlier than the table implies. Investment data are reported as gross totals. They include public and private investment. Efficient policies induce private investment with as little public intervention as possible. For example, the German Bank for Re-construction (KfW) estimates that every euro of public spending in residential credit support programmes induces five euro of private investment.

FIGURE
ENERGY COSTS AND EFFICIENCY IN PRIVATE SECTOR DIFFERENTIATED BY ANNUAL REVENUE

KFW (2005)

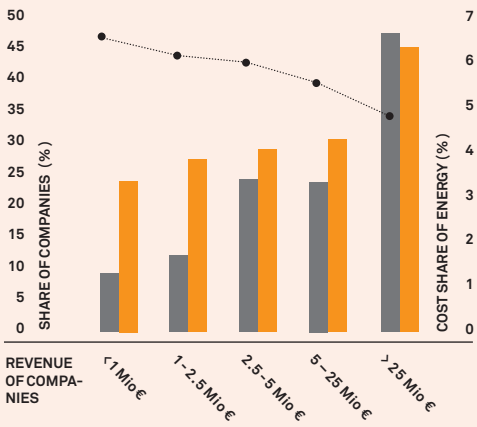
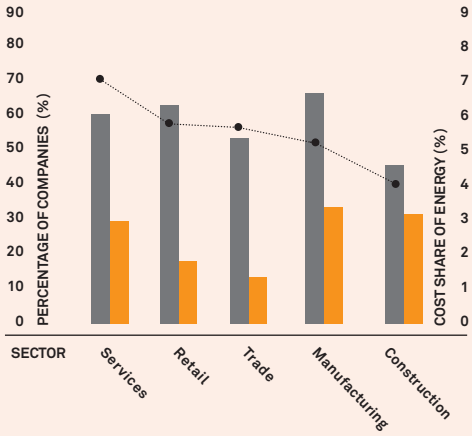


FIGURE
ENERGY COSTS AND EFFICIENCY IN PRIVATE SECTOR DIFFERENTIATED BY SECTORS

KFW (2005)

ENERGY SHARE OF TOTAL COST ●
IS EE A PRIORITY?
EE MEASURES ALREADY UNDERTAKEN

KfW surveyed energy efficiency measures among small to medium-sized companies in Germany. The left panel below indicates that small firms tend to have a relatively higher share of energy in total cost (blue line). At the same time they lag behind in regard to the implementation of energy efficiency measures (blue bar). Smaller firms have tended to finance investments internally or rely on public support programmes without taking loans from banks. The right panel below shows that service and retail companies have higher shares of energy costs than construction and manufacturing companies. Though the former group appears to be aware of the issue, a comparatively low proportion of firms has already implemented energy efficiency improvements. The survey suggests that credit support programmes targeted at small firms in the service and retail sectors are a particularly promising way of delivering energy savings.Credit programmes should be accompanied by information campaigns to raise awareness of opportunities among these firms.



Another example of energy inefficiency is the Russian gas pipeline system. First, leaks of natural gas (methane) are especially worrisome because these emissions have a high global warming potential compared with the CO_2 deriving from its combustion. Second, pipeline leaks increase the recompression required, which in turn consumes more power. Third, more compression still further increases emissions because this process step is particularly prone to gas leakage. Fourth, gas flaring from crude oil production is wasteful and creates yet more emissions. The Table below summarises the energy losses and emissions as well as their cost-effective mitigation potential. Current emissions are equivalent to 14% of Russia's total GHG emissions. Realising the potential is also in the interest of Russia's trading partners in Western Europe, because higher efficiency improves their availability of natural gas.

TABLE
ENERGY LOSSES, EMISSIONS AND COST EFFECTIVE MITIGATION POTENTIAL FOR RUSSIAN GAS PIPELINES

IEA (2006)

	PETAJOULE (PJ)		$MtCO_2eq$	
	GAS LOSSES	REDUCTION POTENTIAL	EMISSIONS	MITIGATION POTENTIAL
GAS DISTRIBUTION LEAKS	183	121	80	53
GAS COMBUSTION OF COMPRESSORS	1414	283	82	16
COMPRESSOR & TRANSMISSION PIPELINE LEAKS	213	86	93	37
GAS FLARING	517	506	43	43
TOTAL	2327	996	298	149

UPGRADE PHYSICAL INFRASTRUCTURE

Appropriate infrastructure design is a key way of integrating new emissions abatement technologies into existing structures. In many cases, building infrastructure requires large up-front investments, but the associated social benefits cannot be fully appropriated by private investors. They are therefore under-provided by the market, requiring policy-makers to intervene. Appropriate infrastructure investment can generate considerable social returns as it enables private investors to supply products and services to larger markets and decreases input costs.

SPEED Not all infrastructure projects can be implemented quickly; many require a prolonged phase of planning and deliberation. Priority should be given to infrastructure that is ready to be built. In addition, as currently all signs suggest that the global economy is unlikely to emerge from recession soon, infrastructure projects that are currently in their planning phase should be accelerated, as they could be a helpful way of increasing aggregate demand in the later stages of the economic crisis.

MULTIPLIER In times of recession, the construction sector suffers particularly heavily as demand for construction of new buildings slumps and overcapacity build up. Hence investments in infrastructure projects can have high multipliers. This is confirmed by the findings of IMF (2009a) country teams and model-based research, prepared for the G20 Meeting of the Deputies, in which infrastructure investments show the highest average multipliers, ranging from 0.5 to 1.8.

LONG-TERM CLIMATE BENEFITS Infrastructure investment by itself does not necessarily imply gains for the climate. However, having the appropriate infrastructure in place is a necessary precondition for harnessing the potential of novel climate-friendly technologies. Given the long life-time of most kinds of infrastructure, it is of crucial importance to act with foresight and take the right decisions now in order not to lock in high carbon emissions on an ultimately unsustainable growth path.

▶ We recommend that G20 members assess with urgency the need for and feasibility of infrastructure investments in the following four areas:

1. **ELECTRICITY GRID EXTENSIONS AND UP-GRADING** improve the efficiency of renewable energy carriers and increase the grid's accessibility to the cleanest and most modern energy carriers. Broad, affordable and reliable provision of electricity can improve the return of many private investments (see Box 2)

2. **PUBLIC TRANSPORT** saves time and improves the functioning of labour markets with high energy efficiency. Moreover, public procurement of vehicles can set emission standards for CO_2 and local air pollutants.

3. **INTEGRATED FREIGHT TRANSPORT SYSTEMS** ease cross-border trade and, if using rail, can contribute to the decarbonisation of transport by facilitating the switch from petroleum products to electricity generated from carbon-free energy sources.

4. **CO_2 PIPELINES** for CCS projects connect sources of emissions with CO_2 sinks. Co-ordination and public support of pipeline construction can reduce costs compared with privately planned pipelines.

As infrastructure generally has a lifetime of several decades, it is important to take into account the potential impacts a changing climate will have in the future on infrastructure being planned now. G20 nations will be affected by the unavoidable aspects of climate change, such as water scarcity, sea-level rise and increased frequencies of tropical storms. To deal with the associated impacts, targeted investments in infrastructure will be required. However, relatively little is known about optimal adaptation strategies and existing knowledge is hard to generalise because of the highly country-specific nature of these impacts. In addition, many of these impacts are likely to materialise in the more distant future, so that investing in adaptation infrastructure at a later stage is likely to be a more suitable approach.

BOX 2
PREPARING ELECTRICITY GRIDS FOR RENEWABLE INTEGRATION

In mature economies, electricity grids are inherited from the past, when the generation mix was based on large-scale centralised and 'dispatchable' power plants. These grids now need to be upgraded so that they can absorb substantial volumes of fluctuating electricity flows from renewables, especially wind. Otherwise, limited distribution capacity will force wind farms to decrease dispatch frequently, thus reducing the return on green electricity investments. Necessary system modifications comprise electro-technical control equipment, transmission lines and low-carbon back-up generation and storage capacities. The required investment costs are estimated to be below 10% of the total green generation capacity investment requirement.

Grid-related investments usually have long lead times. However, some extensions to the transmission grid can be implemented very quickly, as plans for grid upgrades have been under preparation for several years in many countries. For instance, additional cables can be added to existing electrical towers. This is also possible at already congested cross-border connections in Europe.

Numerous studies have assessed the potential for grid extensions and control facilities. The Table below summarises some results by reporting the different targets for wind power installation and the estimated investment costs for off-shore and on-shore grids as well as wind turbines and, in the case of off-shore wind-parks, the cost for connection with the on-shore grid. It turns out that wind turbines are the main cost driver, followed by grid connection. Investment needs for the preparation of on-shore grids are relatively modest. However, these investments are essential for integration of large amounts of off-shore wind into the existing electricity network.

Targets partially include expansions in generation capacity that are currently under construction or in final planning stage. The number for Europe needs to be put into perspective with respect to expectations about future developments. The European Wind Energy Association (EWEA) estimates that up to 180GW of wind power could be installed by 2020, delivering 15% of Europe's electricity demand. This will only be in line with maintaining high levels of system stability if sufficient investment in on-shore transmission grids is undertaken. Hence, the numbers cited above need to be revised if higher penetration of wind power is achieved.

A country of particular concern is India. The electricity sector needs to grow rapidly to modernise all parts of the country. This mostly involves improving the low efficiency of coal power plants and the electricity grid. Moreover, the country is well-endowed with hydro, wind and solar energy resource potential. Only a small part of this potential has yet been realised, though 25% of all recently installed capacity is in the renewables sector. This rapidly growing infant industry may need support to bridge the current credit crunch. India faces the great challenge and opportunity of developing a grid infrastructure that can integrate large shares of renewables. Low-carbon growth in India should be seen as a means to achieve the Millennium Development Goals targeting energy poverty, local air pollution and global warming.

TABLE
TARGETS FOR WIND POWER AND INVESTMENT NEEDS IN GRID EXTENSION AND GENERATION CAPACITIES IN SELECTED COUNTRIES

	TARGET FOR WIND POWER	GRID ON-SHORE	CONNECTION OFF-SHORE	WIND TURBINES	REFERENCE
GERMANY	18.6GW off-shore	-2010 € 500 mio -2015 € 350 mio -2020 € 1800 mio	North S.: € 10 bn Baltic S.: € 0.6 bn		dena (2005)
NETHERLANDS	6GW off-shore	€ 300 mio	€ 1.8 bn	€ 8.5 bn (off-shore)	Engel (2004)
IRELAND UK	4GW until 2020 20% until 2020 30% until 2020	€ 500 mio £ 400 mio £ 1.3 bn		€ 5bn (on-shore)	AIGS (2008) Strbac (2002)
USA	20% until 2030			US $ 200 bn (on-shore)	USDOE and NREL (2008)

- We recommend that G20 members ensure that new infrastructure investments are 'climate proof', i. e. that they take into account the impacts of unavoidable climate change. Regular exchange of information and the establishment of a common set of criteria would facilitate this task. G20 members should take steps to initiate country-specific assessments of vulnerabilities to climate change and optimal adaptation strategies. G20 members should further identify the optimal timing as well as the required amount of investment in adaptation infrastructure.

Infrastructure also has an explicitly international dimension, as it facilitates trade as well as movement of people between countries. In the context of green

spending, pipelines and trans-boundary electricity grids are probably the most important issues. For example, improvements in the pipeline infrastructure through international technology support benefits the exporter as well as importing countries.

- We recommend that G20 members use existing international forums and treaties to initiate additional co-financing and technology transfer for trans-boundary pipeline and electricity grids.

SUPPORT CLEAN-TECHNOLOGY MARKETS

Firms engaged in developing and producing clean energy sources are at particular risk in the current crisis. First, since the start of the economic crisis, primary energy and carbon prices have fallen sharply, rendering clean-energy technologies less competitive. Second, clean-energy technology firms are particularly affected by current credit market constraints. They frequently face relatively high capital costs as well as higher risk premiums because of the innovative technologies they employ. As a result, project finance has been drying up and potential investors have shifted towards outdated, more polluting technologies with smaller initial capital costs. Potential successors to the first wave of innovating firms may have available the financial means, but the transfer of ownership rights from their failed predecessors is likely to take years in some cases.

SPEED Numerous financial schemes to support clean-energy technologies exist already, e.g. production tax credits, feed-in tariffs and facilitating access to credit. Schemes can be initiated, augmented or extended within a short period of time and will start to exert a stimulating effect on the economy as soon as they are implemented.

MULTIPLIER Market observers (e.g. A.T. Kearney, 2009) see many clean-energy firms at risk because order books are shrinking and banks reducing lending. The lack of liquidity hampers project implementation at all stages. Project developers defer or even cancel orders because of tightened credit constraints. We therefore expect that fiscal measures targeted at clean-energy technologies will be highly effective in overcoming credit constraints and preventing the decline of these developing industries.

LONG-TERM CLIMATE BENEFITS Given continued growth of the global population and per-capita incomes, the world will very probably need more, not less, energy in the future. Clean energies rank among the most promising options to meet this growing demand while preventing dangerous climate change. If firms supplying these technologies were to collapse in the current crisis, society would not only lose employment and growth opportunities, but also stocks of technology, human capital and organisations that are difficult and time-consuming to re-build.

- We recommend that G20 governments ease temporarily high risk aversion among potential lenders and facilitate financing of clean-technology projects by providing and expanding feed-in tariffs, renewable portfolio standards, production tax credits, guarantees and loans.

  Clean-technology markets are likely to be a major source of future growth in several countries. In Germany, the output of this sector increased by 27% between 2005 and 2007, employing almost 1.8 million people (see Box 3). Governments can mitigate the adverse effectse of the current economic slowdown by directly boosting domestic demand for green technologies and services. For instance, public administrations in EU member countries account for about 5-10% of national energy consumption, totalling €49 billion annually. Greener procurement could reduce energy consumption by 20% by 2020. A good example is the procurement of computers worth €1billion per year (Borg et al., 2006).

- We recommend that G20 governments immediately review and amend national procurement guidelines with the aim of going 'carbon neutral'. Governments should mandate all public installations to source energy for electricity, heating/cooling and transport from renewable sources. Procurement of buildings, vehicles, electronic equipment, etc. should be limited to products with the highest efficiency standards available in the market place.

BMU (2009), BERR (2008)

BOX 3
MARKETS FOR CLEAN TECHNOLOGIES IN GERMANY AND THE UK

In Germany, green technologies play a prominent role, employing almost 1.8 million people and accounting for more than 5% of industrial production. In the period 2005 - 2007, output of environmental goods increased by 27%, and Germany strengthened its position as a world-market leader in renewable energies, waste management, recycling technologies, specialised electronic equipment, and measurement technologies. Recent expert surveys suggest that environmental technologies (especially renewable energies) are expected to outperform conventional industries, such as machine construction or the automotive industry, in the mid-term.

In the same vein, the British government has recently called for a 'green manufacturing and innovation strategy' designed to re-direct economic activity from a contracting financial sector towards industries focused on sustainable development and to reverse the trend of steadily declining manufacturing shares in national production. This strategy aims at creating 1 million 'green-collar jobs' by 2030 by investing heavily in education and infrastructure, as well as R&D. While the UK is already a major exporter of environmental goods and services, estimates indicate that a successful implementation of the green manufacturing strategy could result in a doubling of export volumes of 'green' goods and services – from GBP billion 25 currently to GBP billion 45 in 2015.

On the international level, it is crucial that G20 members find new and innovative ways of mobilising funds for clean-energy investments. As highlighted by UNEP (2009), the Clean Technology Fund (CTF) and the Strategic Climate Fund (SCF) administered by the World Bank may serve as appropriate vehicles. Financial support will be disbursed to developing economies as grants, concessional loans and risk mitigation instruments. The CTF will invest in projects and programmes that facilitate the transfer and adoption of low-carbon technologies in power generation, transportation and energy efficiency. The SCF will target funding to programmes that pilot new development approaches or scaled-up activities. Initial projects include a scaling-up of the renewable energy programme (World Bank, 2008).

- We recommend that G20 members consider significantly expanding the Clean Technology Fund and the Strategic Climate Fund, with a view to incorporating these investment vehicles in the Copenhagen climate change agreement.

In addition, a consensus on supporting clean energy markets internationally should go hand-in-hand with a commitment to free trade and the removal of import barriers for low-carbon technologies. Existing export and, more importantly, import restrictions often reduce the availability of low-carbon technologies, unnecessarily increasing the cost of climate protection.

- We recommend that the G20 strives for a successful conclusion of the Doha Development Round of trade negotiations, especially with a view to dismantling existing trade barriers for clean-energy technologies and services. Furthermore, G20 members should seriously consider facilitating market access for clean energy technologies by unilaterally lowering respective trade barriers.

INITIATE FLAGSHIP PROJECTS

Flagship projects improve our technological knowledge and lead to new products by proving the feasibility of new technologies and making success widely visible. Flagship projects are large in scale. As they offer the possibility for trial-and-error, not all need to succeed. Some projects may fail but still lead to better understanding of the options in various fields and help to develop new solution approaches. Flagship projects involving low-carbon technologies are only likely to be profitable for private investors if a price is put on carbon emissions. Even with carbon pricing, if the associated risks are borne by investors and project developers, without them being able to appropriate fully the rewards if the project turns out to be successful (because imitators enter the market), they will be discouraged from participating. State intervention can be an appropriate means to solve this incentive problem.

SPEED Flagship projects are located at the technology frontier, so that planning and initiating new ones can be a time-consuming process. However, a number of such projects are in the pipeline or awaiting approval. Accelerating the realisation of these projects by providing additional financial means and removing administrative barriers will deliver timely impacts.

MULTIPLIER As initiating flagship projects is an activity that cuts across different industry sectors, it his hard to make general claims about the multiplier effects involved. The multiplier associated with a flagship project depends on its type, e.g. if it involves creation of infrastructure or if it focuses heavily on R&D. In any case, the overall funds required for initiating flagship projects are relatively small compared with the total proposed for green stimulus measures. Rather than providing a direct boost to the economy, flagship projects should best be regarded as accompanying measures to make information available to private investors about areas at which they should aim their investments; in this way, they can trigger substantial investments by the private sector.

LONG-TERM CLIMATE BENEFITS Major technological advances are ultimately indispensable to tackle the climate crisis successfully at moderate cost. While technological breakthroughs are by their very nature hard to predict, creating the conditions under which they are most likely to occur can trigger new inventions and broaden our knowledge with regards to portfolios of technology options suited to decarbonising our economies. By identifying promising new technologies, flagship projects reduce uncertainty and ensure that private sector investments are allocated more efficiently.

▶ We recommend that G20 members assess the feasibility of the following flagship projects:

1. **CARBON CAPTURE AND SEQUESTRATION (CCS)** technologies reduce CO_2 emissions in various sectors like the electricity sector, chemicals, cement, steel, refinery, etc.

2. **CONCENTRATED SOLAR POWER** produces energy without fossil fuels. Electricity can be produced without suffering from diurnal fluctuations. Also high temperatures, useful in several industrial processes, can be generated.[11]

3. **LIQUIDS AND SYNTHETIC GASES FROM LIGNO-CELLULOSIC BIOMASS** can produce transportation fuels and natural gas substitutes without competing for arable land that should serve for food production.

4. **POWER STORAGE** improves the integration of carbon-free, but time-varying, flows of renewable electricity in various ways. This ranges from improving grid integration to electric vehicles and batteries for off-grid installations like solar home systems.

11 See Pitz-Paal (2004) and DOE (2007)

5. **INTEGRATED HYDROGEN SYSTEMS** with low carbon emissions are aimed at reducing emissions along the whole chain from initial production through distribution to final use. These systems may first be applied in niche sectors like ships for fisheries, freight transport, and public transport.

As the financial needs involved are large and success is not guaranteed, sharing costs and risks among G20 members by means of joint flagship projects makes good economic sense. International financing schemes and technology transfer increase the probability of success. The international perspective is particularly important for developing clean and renewable energy technologies that can be applied at large scale in developing countries, while also making new energy technologies attractive for economies that today are highly dependent on the extraction of fossil fuels, provided that they exhibit high renewable energy potential. Free trade aids access to cutting-edge technologies and generates economies of scale to finance the costs of development. International co-ordination reduces welfare losses from duplication of efforts and eases knowledge exchange. Each success will increase our ability to halt climate change, and this is in the interest of all nations.

- We recommend that G20 members take steps to establish research communities aimed at jointly initiating flagship projects, sharing their associated costs and benefits. Participation in these communities and projects shall also be open for non-G20 countries if deemed desirable by the majority of G20 members.

Box 4 on commercialisation of CCS provides a good example. It also shows that we can for the time being largely build on existing technology networks and platforms. This is also valid for the other flagship projects that we do not explain in detail.

BOX 4
COMMERCIALISATION OF CCS

Carbon capture and storage (CCS) has been successfully implemented in a number of projects, e.g. the Sleipner project in the North Sea. Since 1996, 1 million tons of CO_2 extracted along with natural gas production has been separated from the gas stream and injected into geological sub-sea formations. However, existing projects are insufficient to demonstrate the large-scale, continuous separation of CO_2 in power plants and other industrial facilities. CO_2 separation is a proven technology only at the pilot plant level. Large-scale and continuous separation of CO_2 at power plants is the next step for commercialisation of CCS.

Most G20 members have started or are planning CCS projects including demonstration capture plants and injection projects (see Table below). These activities are co-ordinated internationally through the Carbon Sequestration Leadership Forum (CSLF), bringing together 21 countries and a number of other stakeholders.

A number of commercial projects are under way that are financially supported by governments or, as in the case of Australia, by the coal industry. South Africa is a special case, because coal-to-liquid (CTL) plants already separate 400 $MtCO_2$ per year in existing facilities there. The extra effort required for sequestration would be relatively small. However, the local geology often poses constraints. This example as well as the Sleipner project highlights the availability of CCS possibilities beyond the power sector. Other feasible CO_2 capture opportunities include liquefied natural gas (LNG), hydrogen plants, refineries, cement plants and coke ovens.

Future development of CCS will depend on the availability of suitable CO_2 pipelines. International co-ordination and support for the implementation of CO_2 pipelines could deliver economies of scale. For Germany, discounted total investments of € 6 - 8 billion are required to implement pipelines and injection equipment that would be capable to transport 5.2 billion tons of CO_2 from source to sink over three decades. In the UK, investment needs amount to € 7 -10 billion for 3.7 billion tons of CO_2; see Kjärstad and Johnsson (2008). In the USA, a maximum of 1500km annual pipeline construction is expected in stringent climate stabilisation scenarios. This figure is small compared with historical experience of natural gas pipeline construction, which amounted to 8000 km p. a. in the 1970s; see Dooley et al. (2008).

TABLE
OVERVIEW OF CCS PROJECTS IN G20 COUNTRIES

DATA COMPILED FROM VARIOUS SOURCES. MORE DETAILS ARE AVAILABLE FROM PIK. ABBREVIATIONS: OXY-FUEL IS A SPECIAL METHOD FOR CARBON CAPTURE; LNG IS LIQUEFIED NATURAL GAS; CTL IS COAL TO LIQUID; EOR IS ENHANCED OIL RECOVERY; ECBM IS ENHANCED COAL BED METHANE; RCSP IS REGIONAL CARBON SEQUESTRATION PARTNERSHIPS.

COUNTRIES	CAPTURE DEMO PLANTS UNTIL 2010	CAPTURE DEMO PLANTS UNTIL 2015	CAPTURE DEMO PLANTS UNTIL 2020	INJECTION PROJECTS	SEQUESTRATION POTENTIAL
GERMANY	Schwarze Pumpe, 30MW oxy-fuel; €60mn			Ketzin	34GtCO_2
FRANCE	Oxy-fuel; €60mn.			Rousse gas field	
ITALY	Brindisi; 50 MW_{th} oxy-fuel	Torrevaldaliga post-combustion 2000 MW_e		Sulcis coal field	7GtCO_2
UK		Post-combustion 300MW_e			950GtCO_2
EU	Esbjerg, post-combustion; 8 ktCO_2	12 demo plants; total € 10 - 12 bn			
AUSTRALIA	5 projects; e.g. Gorgon LNG, 3.3MtCO_2 p.a.; total A$20bn.	4 projects; e.g. ZeroGen, 80MW_e	2 projects; e.g. Monash CTL, 15 MtCO_2 p.a.	Otway, Victoria	2750GtCO_2
CANADA		Boundary Dam 100MWe post-combustion. Alberta oil sands CCS projects; CA$2 bn; 5 Mt$CO_2$		Weyburn EOR, Alberta ECBM	<1000GtCO_2
CHINA	Beijing, post combustion, 0.3 MtCO_2; Tianijn, 250MW_e pre-combustion			Several EOR and ECBM projects	2000GtCO_2
INDIA	Hydrogen; 0.2MtCO_2 p.a.				1000 GtCO_2
JAPAN	Matsushima; post-combustion 4 ktCO_2				< 160 GtCO_2
SOUTH AFRICA			Demo plant		>100 Gt CO2
USA		6 demo plants		~15 projects (RCSP)	3000 GtCO_2

ENHANCE INTERNATIONAL R & D

In the future, emissions-intensive goods and services will have to be produced in less emission-intensive ways. Halting climate change will involve substantially increased investments at all stages of technological innovation, including basic research and development (R&D), demonstration, deployment and diffusion. Empirical evidence suggests that most low-carbon technologies known today have a sizeable potential for further cost reductions due to learning effects. But significant R&D investments are necessary before these technologies become competitive; see IEA (2008b). Stringent carbon pricing is the single most important policy instrument to mobilise private funds for technological innovation. But the provision of public R&D spending remains important, because market failures exist that lead private investors to undersupply R&D finance even in presence of carbon pricing.

SPEED Limited increases in R&D spending can be triggered relatively quickly by providing resources to universities and research institutes to hire new staff, create new facilities and buy new equipment. Larger increases will take longer, as broad research strategies have to be devised, collaborations identified and concrete propositions evaluated if the associated funds are to be put to the most productive use.

MULTIPLIER It is impossible to be precise about the multiplier effect of increased R&D spending, because of the variety of aspects involved in the process of research and development. In times of economic downturns, R&D undertaken by the private sector is usually scaled back sharply, but state-sponsored R&D is largely shielded from the current recession. In addition, it matters at which stage of the economic value chain the R&D activity is situated. Overall, we expect upscaling of R&D budgets to contribute towards economic stabilisation; however, the implied monetary flows are at least an order of magnitude smaller than spending on energy efficiency, infrastructure, or clean energy technologies. The main benefits of investing in R&D therefore materialise in the long term, when new inventions result in technologies that reduce the costs of reducing greenhouse gas emissions.

LONG-TERM CLIMATE BENEFITS Having the right technologies at hand allows energy to be used more efficiently or a lower amount of GHG emissions to be produced in its generation. Both aspects of technological progress significantly reduce the costs of starting the transition towards a low-carbon economy. Having cheaper carbon-free technologies available will improve the prospects for a global climate agreement by reducing the overall burden to be distributed among participating countries. Furthermore, increasing public funds for climate-related R&D establishes a credible signal for private investors that governments are serious about tackling climate change, and that investing in the development of green technologies now will pay off in the future.

In 2007, global public R&D spending on renewable energy and energy efficiency was US$ 7.1 billion (UNEP and New Energy Finance, 2008). The IEA estimates that energy efficiency and renewables receive only 12% of government R&D funding for the energy sector, compared with 40% for nuclear

technologies. At the same time, overall funds provided for energy R&D are decreasing. In 2005, public spending on energy R&D amounted to only 4% of total public R&D, down from 12% in the early 1980s. This decline is a reason for concern, given the growing urgency of developing low-carbon energy technologies. Numerous recent studies suggest that spending on R&D aimed at energy efficiency and clean energy needs to increase at least three- to four-fold in order to enable the transition to a low-carbon energy system (Bierbaum et al., 2007).

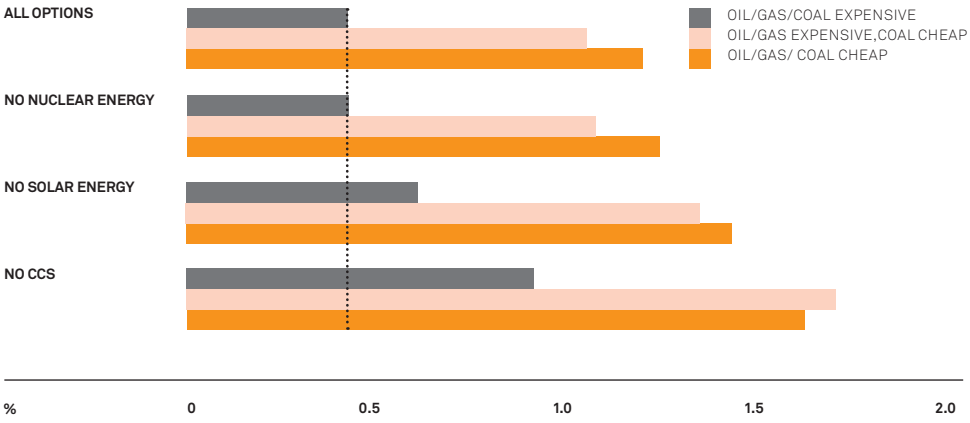
- We recommend that on average, G20 members increase their total spending on R&D related to energy efficiency, renewables and CCS to at least 0.05% of GDP. In addition, G20 members who have not yet done so should establish publicly financed venture capital funds which target innovative clean-energy technologies. Unlike private venture capital, public venture capital can undertake longer-term investments and make investment decisions based on factors such as climate protection and energy security in addition to the expected return on investment. The China Environment Fund and the UK Carbon Trust Venture Capital Fund are two examples of publicly backed funds in this area (UNEP, 2008).

  As investments by one country generate knowledge spill-overs, reducing the costs of new technology for every other country, international co-ordination of R&D efforts can leverage the benefits of every dollar spent.

- We recommend the development of a G20 Strategic Energy Technology Plan (SET Plan), modelled on the European example and building on the IEA Energy Technology Perspectives Report, which could serve to streamline R&D efforts globally. The G20 SET Plan would evaluate the potential for up-scaling joint energy research and identify those technologies for which it is essential that the G20 as a whole finds a more effective way of mobilising resources. Efforts should focus on renewable energy sources and carbon capture and sequestration (CCS), as modelling exercises suggest that these technologies offer the highest option value for climate protection (see Figure 5). The International Renewable Energy Agency and the Carbon Sequestration Leadership Forum may serve as appropriate platforms for G20 action.

FIGURE 5
OPTION VALUES OF MITIGATION TECHNOLOGIES. CONSUMPTION DIFFERENCES IN % (BUSINESS-AS-USUAL – STABILIZATION), COMPARING THE 'ALL OPTIONS' SCENARIO TO SCENARIOS WHERE OPTIONS ARE RESTRICTED TO THEIR RESPECTIVE USAGE IN THE BUSINESS-AS-USUAL SCENARIO (REMIND RESULTS, 3% P.A. PURE TIME PREFERENCE RATE)

EDENHOFER ET AL. (2008)[12]



INCENTIVISE INVESTMENT

Providing a strong, stable carbon price is the single policy action that is likely to have the largest effect in promoting economically efficient low-carbon growth over the longer term. A uniform global carbon price guarantees that emissions are generated where they yield the largest social net benefits, and it allows for maximum flexibility in reducing greenhouse gas emissions at the minimum cost. A strong and joint commitment to achieve universal carbon pricing by G20 leaders would stabilise investors' confidence and boost the expectations of low-carbon technology providers. Putting a universal price on carbon emissions is particularly important for major economies because a co-ordinated carbon pricing strategy can mitigate the concerns of industrial sectors facing international competition that carbon-intensive activities would simply relocate to other countries.

A price on carbon, and a firm commitment to carbon pricing in the future, will influence market participants' expectations, ensuring that investment triggered by fiscal spending promotes low-carbon technologies and sustained growth and employment instead of locking in ultimately unsustainable methods of production and consumption. Without a credible commitment to carbon pricing, fiscal spending from national stimulus packages runs the risk of building up long-lived capital stock that is geared towards the use of fossil energy carriers, making decarbonisation in the future much more difficult and expensive. The recent sharp fall in the European carbon price[13] might reduce the short-term cost burden for carbon-intensive firms, but it also delays the structural transition required to achieve a low-carbon economy. It is crucial that

12 PIK energy-economy model simulations show that some mitigation options are more important for achieving ambitious mitigation targets at moderate costs than others. The difference in mitigation costs in the 'all options' scenario employing all technological options and the 'all but one option' scenario indicates a technology's option value. Simulations show that fixing nuclear energy at the business-as-usual level would only result in marginally higher mitigation costs. Solar power and CCS, by contrast, have greater option values. This result is relatively robust as it is consistent across different energy-economy models (see Knopf et al., 2009).
13 The price of allowances in the EU ETS has decreased by 60% since summer 2008. The current price level of about € 12 per tonne of CO_2 is likely to be too low to boost investments in low-carbon energy technologies such as renewables and carbon capture and sequestration.

policy-makers strengthen the market outlook by clearly and firmly committing to a stringent global carbon pricing framework. Firms and households need a steady, long-run signal about the economic costs of emission-intensive technologies so that investing in technologies to mitigate greenhouse gas emissions becomes profitable. Apart from reducing investment uncertainty now, stringent carbon pricing also helps to avoid potential rebound effects from improvements in energy efficiency. Investments in energy efficiency raise disposable income by reducing the cost of carbon-intensive activities. Without a price on carbon, freed-up income will boost the consumption of carbon-intensive goods and services once the economy recovers.

- We recommend that the G20 commit to striving for a global cap-and-trade system that establishes a world-wide limit on GHG concentrations, including credible short, medium and long-term targets. A global carbon market with one single carbon price ensures that emitters have the flexibility to reduce emissions wherever this is cheapest. Global carbon trading may be implemented via UNFCCC negotiations, or bottom-up by linking regional schemes in the context of the International Carbon Action Partnership (ICAP). These approaches can complement each other. All OECD countries should implement national cap-and-trade systems as soon as possible. Developing countries may wish to be assured of the commitment of developed countries to low-carbon growth before committing to emissions caps but should in the short term participate by means of one-sided trading mechanisms such as a reformed Sectoral Clean Development Mechanism.

CO-ORDINATE G20 EFFORTS

G20 nations' fiscal response to the current crisis will benefit from close co-operation and co-ordination among governments for four reasons:

First, stabilisation measures in one country will increase that country's demand for imports and therefore have a beneficial spill-over effect on the rest of the world. Considering the extreme case of an open economy with a flexible exchange rate, an increase in government spending will lead to appreciation of the exchange rate, fully crowding out exports, and be of zero (domestic) effectiveness in the end – unless accompanied by accommodatory monetary policy. However, representing the world's major economies, the G20 as an aggregate is close to being a large closed economy, in which the benefits of public spending are fully internalised.

Second, joint efforts by G20 leaders to tackle the economic crisis can go some way to restore confidence and act as a signal that a recovery is likely. Management of expectations is crucial to reduce uncertainty and break the current deadlock in which expectations of a worsening economic environment turn into self-fulfilling prophecies.

Third, sizable and well-targeted green fiscal stimulus measures in G20 countries constitute a valuable first step towards putting the world economy on a low-carbon growth path. The prospect of having new climate-friendly technologies and infrastructure available in the near future is likely to create confidence and pave the way for the negotiations on a global climate agreement, which will take place in Copenhagen in December.

Fourth, governments acting in isolation may feel tempted to opt for competitive devaluation of their currencies or raise tariffs and other trade barriers to strengthen demand for domestic industries to the detriment of imports. These so-called 'beggar-thy-neighbour' policies are very likely to result in an economically inefficient structure of production and higher costs for households. They could easily provoke retaliation, resulting in a situation in which a slowdown in world trade further drags down an already slumping world economy. The same argument applies to clauses designed to aim fiscal stimulus measures at domestic industries while discriminating against foreign suppliers, especially in public procurement.

- The effectiveness of fiscal measures can significantly gain from co-ordinating G20 efforts towards a global green recovery. We recommend that the G20 members reaffirm their commitment to an open trading system and refrain from discriminatory provisions in national stimulus packages.

One of the key messages that has emerged clearly from this paper is that there is a great lack of knowledge regarding the actual and appropriate size of green fiscal stimulus measures, the associated multiplier effects and their potential to create employment. Undertaking further research is necessary to ensure that green stimulus measures can be better designed.

- We recommend that G20 members appoint 'Energy & Climate Sherpas' to co-ordinate follow-up meetings and ensure that momentum in developing policies is maintained. As much further work is needed to fill existing knowledge gaps, sherpas may consider setting up an expert group to help devise the optimal design of G20 green recovery programmes.

5 OUTLOOK

The current economic contraction and the growing interest of national governments in kick-starting a world-wide recovery represent an opportunity to tackle important long-run economic and environmental challenges together. Fiscal measures aimed at economic recovery and job creation can and need to be made compatible with developing a low-carbon world economy. Above, we have highlighted seven strategic areas for G20 action which, if implemented, would help to foster sustainable economic growth, create jobs and wealth, avoid dangerous climate change and reduce sources of global instability such as energy insecurity and resource competition.

Follow-up summits after London are at risk of taking place in a still worsening macroeconomic context. As the current outlook indicates, additional fiscal stimulus measures might be required. The IMF suggested last December that the G20 collectively should undertake a fiscal expansion of around 2% of annual GDP very soon. Other studies suggest that in the light of subsequent large downward revisions in projections of growth over the next two years, a higher figure – perhaps around 4% – might move into the centre of discussions.[14] Additional regulatory and fiscal packages of individual countries need to be diversified and should tackle, in particular, the malfunctioning of the global financial system. But a fair share – around a fifth on average – of additional funds should be directed towards 'green' measures to fill the gap caused by slumping private sector investment and raise the extra capital that will be required to decarbonise the global economy. First estimates suggest that the proportion of fiscal stimuli announced so far is approaching that fraction, but more can be done. In any case, all public spending should avoid locking countries into ultimately unsustainable high-carbon activities for years to come.

Once economies recover, the need for some public-sector support in most of the above outlined areas will not completely evaporate, given the nature of the relevant market failures. Avoiding dangerous climate change requires persistence over the long term in carbon pricing and technology support, while recognising that the balance between public and private funding will have to change as economic recovery takes hold. Future action will have to be taken responsibly, in the context of a clear long-term framework that will ensure fiscal sustainability as well as sustainable growth. That entails developing an incentive structure, including carbon pricing, that passes more responsibility for tackling climate change to the private sector over time. The decisions made during the upcoming UNFCCC Summit in Copenhagen will be critical for developing such an incentive structure geared towards low-carbon growth. Leaders should credibly reaffirm their commitment to establish an ambitious post-Kyoto architecture later this year.

The main message of this report is one of confidence. Confidence that G20 leaders will shape an opportunity out of the current crisis. Once economic recovery is under way, markets have to deliver a different quality of growth that is more sustainable – a return to past production patterns is economically neither wise nor desirable. The growth-based agenda of building a low-carbon world economy can deliver immediate and long-term economic benefits, cut the risk of dangerous climate change thereby laying the foundation for sustainable growth and future prosperity.

14 see for example Bowen et al. (2009)

APPENDIX: THE COSTS OF INACTION AND ACTION

The economics of climate change has established clearly that the costs of inaction are likely to outweigh heavily the costs of action against anthropogenic climate change. The arguments are rehearsed here. Economics can also inform the design of policy frameworks and instruments to ensure that action is carried out equitably and cost-effectively. Ultimately, however, action on climate change is necessarily a matter for ethics and social decision-making.

COSTS OF INACTION

At the same time as the world faces an unprecedented economic crisis, it also faces the threat of a climate crisis. Economic activity around the world continues to generate greenhouse gas (GHG) emissions, which through the 'greenhouse effect' lead the Earth to retain more of the solar energy it receives. The costs of doing nothing to tackle this problem depend on, first, how fast GHGs will build up in the atmosphere if 'business as usual' is allowed to continue; second, what impact that build-up will have on climatic conditions around the world; and, third, what the impacts of the ensuing climate change will be and how we value those impacts.

The quantity of greenhouse gases in the atmosphere is increasing, because of human activities. The atmospheric concentration of GHGs has increased from around 285 ppm CO_2eq in pre-industrial times to around 430 ppm CO_2eq. The pace of increase has been picking up. Over the long term, with 'business as usual', the stock of GHGs is likely to continue to increase at around this rate, with concentrations reaching well over 650 ppm CO_2eq by the end of this century. As Garnaut et al. (2008) have argued, past projections have probably underestimated the trend increase. And the build-up could be even faster, given that temperature increases may release methane locked up in perma-frost and the ocean's capacity to absorb CO_2 may be less than originally thought. Such a build-up would not be prevented by the exhaustion of the world's hydrocarbons, given the stocks of coal and unconventional oil resources reported by the International Energy Agency.[15] The current global slowdown is likely to slow emissions growth temporarily, but only pushing back the trajectory of emissions by a year or so.

GHG concentrations of 650 ppm CO_2eq or more would entail an expected increase in global mean temperatures of more than 4°C, with a significant probability of increases above 5°C, according to work by the Hadley Centre and PIK (Meinshausen, 2006) – the same temperature difference that separates us from the last Ice Age. The change in temperatures would be at a speed without precedent. It would bring with it climate changes, higher sea levels as polar ice melted and ocean acidification. The frequency of droughts and floods would increase. Storms would have greater strength. The availability of clean water would be reduced. Changes in climate in many regions would be too rapid for many plant and animal species to adapt. And there would be a

15 See International Energy Agency World Energy Outlook, various years

risk of triggering catastrophes such as the collapse of the West Antarctic ice sheet and the death of the Amazonian rain forest, amplifying the impact of emissions from economic activity.

Such effects would have drastic consequences for societies, particularly the poorest. Agricultural productivity would be reduced. Fishing and tourism would be hit. The infrastructure of transport, communications and utilities supply would suffer more rapid depreciation. Heat-related illnesses and some diseases would become more of a threat. Extreme weather would cause more loss of life. Water shortages would become more severe. The economic development of today's poorest countries would be much more difficult. There would probably be large movements of people, displaced by drought and flooding, giving rise to large-scale conflicts. Together with effects in markets, that would transmit impacts from the worst-hit regions to the rest of the world.

Many of the adverse impacts could be cushioned by appropriate adaptation by firms, households and governments. However, the larger the climate change, the more difficult and expensive adaptation will become. And it is more difficult to adapt to climate change when the local effects are potentially large but uncertain. Some adaptations, such as increased refrigeration and air conditioning, could worsen the climate problem.

Coping with uncertainty is intrinsic to the whole climate change challenge, not just to adaptation. There are uncertainties about the future trajectory of GHG emissions, the climate science and the local impacts and economic consequences of any given extent of climate change. That complicates policy-making and imposes costs on risk-averse people. For society as a whole, it makes sense to manage these huge uncertainties by applying the principle of insurance – paying a premium to guard against the most severe downside risks crystallising if 'business as usual' continued. It also makes sense to give more weight to the worse outcomes, because people on average will be less well-off than in the better outcomes.

Uncertainty is one of the problems that have to be confronted when attempting to estimate the cost of inaction. Another is how to value losses not measured in the market place, such as the disruption of societies. A third is how to model long-term economic growth and whether it is likely to be affected by climate change. A fourth problem is deciding what weight to put on climate-change damages that occur in the future.

These problems explain why it is impossible to be confident about the precise costs of inaction in monetary terms. But it is important not to ignore the costs that are particularly uncertain or difficult to value. Some efforts have been made to come up with a 'ball-park' estimate. Stern (2007) concluded that the costs of climate change over the next two centuries, under business as usual, could be similar in magnitude to a loss of 15% of global consumption per head, now and forever. But, as that Review itself made clear, ultimately it is a

matter of collective judgement by people around the world what risks they want to run with the planet. Whatever metric is used, those risks are very large if no action is taken. Given the global negative externality at the heart of the issue, markets by themselves cannot be expected to contain those risks.

COSTS OF ACTION

When due regard is given to downside risks, the costs of inaction are very high. In contrast, the costs of halting climate change (and adapting to what cannot be avoided) are likely to be much lower, if sensible policies are enacted globally and the extent of necessary action agreed. These costs will arise because of changes in relative prices and technologies of production. Households will have to alter their consumption patterns when faced by higher prices for some products (relative to incomes). Firms will have to scrap emissions-intensive capital equipment (especially in the initial transition to an appropriate emissions reduction trajectory). Activities that are currently emissions-intensive are likely to be more costly, unless and until induced technical progress in low-carbon ways of carrying them out is sufficient to drive down their costs. The incremental costs of increased R&D and investment in low-carbon production have to be taken into account. The overall costs will also depend on how much the global pattern of production will be distorted if climate-change policies are not applied with equal vigour everywhere. Where policy-makers try to suppress relative price increases, resources will be misallocated and real incomes lower.

However, there are also likely to be offsetting factors, which could even outweigh the costs in certain circumstances:

- *There are likely to be ancillary benefits, such as reduced local pollution and greater energy security.*
- *If induced technical change is more rapid in low-carbon activities than in the ones they replace, that will reduce costs at some point in the future.*
- *Policies to fight climate change need to tackle various market failures, which might otherwise have been left untouched. Examples include: the under-provision of innovations due to difficulties in appropriating the returns to them; under-investment due to unequal access to information; and the lack of clarity about ownership rights in tropical forests.*
- *If policies lead to the use of resources that would otherwise be left idle, costs will be reduced (a 'Keynesian' offset).*
- *If policies bring about a change for the better in entrepreneurs' perceptions of future growth opportunities, they could unleash a more general stimulus to innovation and demand (a 'Schumpeterian' offset).*

The costs of action against climate change will be kept to a minimum if, within a global constraint on cumulative GHG emissions, firms and households have freedom to decide how to bring about the necessary reductions, subject to a broadly equal carbon price across the world, because a tonne of emissions imposes the same costs wherever it is emitted. Policy should enlist the profit motive to help find the cheapest ways of meeting the policy objective, which means giving firms 'which, where, when' flexibility:

- *which greenhouse gas emissions to reduce (e.g. CO_2 or methane?),*
- *at which locations to reduce them (e.g. Germany or China?), and*
- *how quickly to reduce them (e.g. a 'quick fix' now or an investment that will bring emissions down more later?)*

The costs of action will also depend on how quickly and how far countries reduce their GHG emissions. Large reductions will entail decarbonising activities for which, at the moment, no alternative low-carbon technologies exist to carry them out at scale. Rapid reductions will put a greater burden on existing low-carbon technologies before enhanced R&D has increased their productivity, resulting in higher costs. But delay risks firms undertaking investment that locks in high-carbon technologies for decades to come, making it necessary to bring about sharper and more expensive emission reductions later.

As with the damages from unrestrained climate change, it is difficult to be precise about the costs of action, although the range of uncertainty is probably considerably less in the latter case. In the 'bottom-up' approach to the estimation of abatement costs, the potential to reduce emissions in particular activities is estimated. For example, McKinsey & Company (2009) find that annual global GHG emissions could be reduced by 35% by 2030 (relative to 1990 levels) at an annual cost by then of EUR200-350 billion – less than 1% of forecast global GDP to be on the path to stabilisation at 500 ppm CO_2eq.

In the 'top-down' approach, large-scale macroeconomic models are used to trace the wider economic impacts of policies to halt climate change.[16] This has the advantage over the bottom-up approach of capturing more of the knock-on effects but it usually cannot use much sectoral detail. The IPCC (2007) review of estimates using this approach found that the global costs of stabilising GHG concentrations would be between 5.5% and -1% of annual GDP by 2050 (some studies calculate net gains to abatement activities even without factoring in benefits of averted climate change), depending on model assumptions and the stabilisation target (ranging from 445 to 710 ppm CO_2eq). The Stern Review concluded that to stabilise eventually at around 500-550

16 Together with Fondazione Eni Enrico Mattei (FEEM) and Centre International pour l'Environnement et le Développement (CIRED), PIK is currently conducting an in-depth comparison of energy-economy models (RECIPE – Report on Energy and Climate Policies in Europe) to assess global mitigation options and costs on regional and sectoral levels. First results will be made available in May 2009.

FIGURE 6
MITIGATION COSTS, WORLD

MITIGATION COSTS FOR THE 550PPM, 450PPM AND THE 400PPM CO_2eq SCENARIOS AS ASSESSED BY FIVE DIFFERENT INTEGRATED CLIMATE ENERGY-ECONOMY MODELS. FOR E3MG, MERGE AND REMIND, THE MITIGATION COSTS (GAINS FOR E3MG) ARE GIVEN AS CUMULATIVE GDP LOSSES UP TO 2100 RELATIVE TO BASELINE IN PERCENT OF BASELINE GDP. POLES AND TIMER REPORT THE INCREASE OF ABATEMENT COSTS RELATIVE TO BASELINE IN %GDP. THE DISCOUNT RATE IS 3%; GDP GROWTH RATES ARE BETWEEN 2.1% AND 2.4% PER ANNUM

KNOPF ET AL.(2008)

ppm CO_2eq would cost around 1% of GDP by 2050 (+/- 3%). More recent energy-economy model comparisons suggest that the costs of an ambitious low-stabilisation scenario of 400 ppm CO_2eq lie below 2.5% of GDP until 2100 (see Figure 6). The key conclusion to be drawn from these estimates is that the costs of action can be much less than the costs of inaction. Thus, strong and urgent action makes economic sense.

REFERENCES

ADB (2009) Global financial turmoil and Emerging Market Economies: Major contagion and a shocking loss of wealth? Asian Development Bank.

AIGS (2008) All Island Grid Study. Department of Communications, Energy and Natural Resources, Ireland.

A.T. Kearney (2009) Renewable Energy Markets – Will the boom go bust?

BEA (2009) U.S. International Trade in Goods and Services. Exports, Imports, and Balances.

BERR (2008) Manufacturing: New Challenges, New Opportunities.

Bierbaum, R., J.P. Holdren, M. MacCracken, R.H. Moss, and P.H. Raven [coordinating lead authors] (2007) Confronting Climate Change: Avoiding the Unmanageable and Managing the Unavoidable. Scientific Expert Group Report on Climate Change and Sustainable Development. Prepared for zthe 15th Session of the Commission on Sustainable Development.

BMU (2009) Umweltwirtschaftsbericht 2009. Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (BMU), Berlin.

Borg, N., Y. Blume, S. Thomas, W. Irrek, H. Faninger-Lund, P. Lund, and A. Pindar (2006) Release the power of the public purse. Energy Policy, Vol. 34:238-50.

Bowen, A. S. Fankhauers, N. Stern, and D. Zenghelis (2009) An outline of the case for 'green' stimulus. Grantham Research Institute on Climate Change and the Environment and Centre for Climate Change Economics and Policy, Policy Brief February 2009.

Canadell, J. G., C. Le Quéré, M. R. Raupach, C. B. Field, E. T. Buitenhuis, P. Ciais, T. J. Conway, N. P. Gillett, R. A. Houghton and G. Marland (2007) Contributions to accelerating atmospheric CO_2 growth from economic activity, carbon intensity, and efficiency of natural sinks. Proceedings of the National Academy of Sciences of the United States of America, 104, 18866-18870.

DCEN (2008) All Island Electricity Grid Study. Department of Communications, Energy and Natural Resources, Ireland.

DENA (2005) Dena Grid Study. Berlin, Germany.

DOE (2007) Solar Energy Technologies Program. Report to Congress on Assessment of Potential Impact of Concentrating Solar Power for Electricity Generation. Report no. DOE/GO-12007-2400, 7. US Department of Energy, Washington DC.

Dooley, J.J., Dahowski, R.T., Davidson, C.L. (2008) Comparing Existing Pipeline Networks with the Potential Scale of Future U.S. CO_2 Pipeline Networks. Paper presented at the GHGT-9, Washington DC, 16 - 20 November 2009.

EC (2009) Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – Towards a comprehensive climate change agreement in Copenhagen COM/2009/0039 final.

Edenhofer, O., G. Luderer, C. Flachsland, and H.-M. Füssel (2008) A Global Contract on Climate Change. Potsdam Institute for Climate Impact Research, Potsdam.

Engel, J. (2004) Elektriciteitsinfrastructuur op zee voor 6000 MW windvermogen. University of Delft.

Feijoó, M.L., Franco, J.F., José M. Hernández, J.M. (2002) Global warming and the energy efficiency of Spanish industry. Energy Economics Vol. 24, pages 405 – 423.

Fuller, M.C., S. Compagni Portis, and D.M. Kammen (2009) Toward a Low-Carbon Economy. Municipal Financing for Energy Efficiency and Solar Power. Environment 51 (1).

G20 (2008) G20 Summit on the Financial Markets and the World Economy. Declaration, November 15, 2008.

Garnaut, R, S. Howes, F. Jotzo, and P. Sheehan (2008) Emissions in the Platinum Age: the implications of rapid development for climate change mitigation. Oxford Review of Economic Policy Vol. 24, No. 2, summer, pages 377-401.

Houser, T., S. Mohan, and R. Heilmayr (2009) A Green Global Recovery? Assessing US Economic Stimulus and the Prospects for International Coordination. Peterson Institute for International Economics and World Resource Institute.

IEA (2002) Electricity in India. IEA, Paris, France.

IEA (2006) Optimizing Russian Natural Gas. Reform and Climate Policy. In Support for the G8 Plan of Action. Paris, France.

IEA (2007a) Energy Balances of OECD Countries (2007 edition)

IEA (2007b) Energy Balances of Non-OECD Countries (2007 edition)

IEA (2008a) World Energy Outlook. Paris, France.

IEA (2008b) Energy Technology Perspectives. Paris, France.

IMF (2008a) World Economic Outlook Database. October 2008 Edition.

IMF (2008b) The IMF and Its Future. Dominique Strauss-Kahn, Managing Director of the International Monetary Fund. Speech at the Banco de España, Madrid, Spain

IMF (2009a) Group of Twenty Meeting of the Deputies. Note by the Staff of the International Monetary Fund.

IMF (2009b) World Economic Outlook. Update January 28, 2009.

IMF (2009c) The Size of Fiscal Expansion: An Analysis for the Largest Countries.

Indian Planning Commission (2006) Integrated Energy Policy. Report of the Expert Committee. New Dehli, India.

IPCC (2007) Climate Change 2007: Mitigation, Contribution of Working Group III to the Fourth Assessment Report of the IPCC [B. Metz, O. R. Davidson, P. R. Bosch, R. Dave, L. A. Meyer (eds)], Cambridge and NY, USA: Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Kjärstad, J., Johnsson, F. (2008) Ramp-up of large-scale CCS infrastructure in Europe. Paper presented at the GHGT-9, Washington DC, 16-20 November 2009.

Knopf, B., O. Edenhofer, T. Barker, N. Bauer, L. Baumstark, B. Chateau, P. Criqui, A. Held, M. Isaac, M. Jakob, E. Jochem, A. Kitous, S. Kypreos, M. Leimbach, B. Magné, S. Mima, W. Schade, S. Scrieciu, H. Turton, D. van Vuuren (2009) The economics of low stabilisation: implications for technological change and policy. In M. Hulme, H. Neufeldt (Eds) Making climate change work for us – ADAM synthesis book, Cambridge University Press.

Lenton, T. M., H. Held, et al. (2008) Tipping elements in the Earth's climate system. Proceedings of the National Academy of Sciences of the United States of America 105 (6): 1786-1793.

McKinsey&Company (2008) The Case for Investing in Energy Productivity. McKinsey Global Institute..

McKinsey&Company (2009) Pathways to a low-carbon economy. January 2009.

Mabey, N. (2009) Delivering a Sustainable Low Carbon Recovery. E3G, March 2009.

Meinshausen, M. (2006) What does a 2°C target mean for greenhouse gas concentrations? A brief analysis based on multi-gas emission pathways and several climate sensitivity uncertainty estimates. In Schellnhuber at al (2006) (editors): Avoiding dangerous climate change, Cambridge University Press, Cambridge, UK.

Murphy, JM. et al. (2004) Quantification of modelling uncertainties in a large emsemble of climate change simulations. Nature Vol 430, pages 768-772.

New Economics Foundation (2008) A Green New Deal. The first report of the Green New Deal Group.

Pitz-Paal, R., J. Dersch, B. Milow (2004) European Concentrated Solar Thermal Roadmapping, ECOSTAR, DLR, Germany.

Pollin, R., H. Garrett-Peltier, J. Heintz, and H. Scharber (2008) Green Recovery – A Program to Create Jobs and Start Building a Low-Carbon Economy. Centre for American Progress, September 2008.

Prasad, E., and I. Sorkin (2009) Assessing the G-20 Economic Stimulus Plans: A Deeper Look. The Brookings Institution.

Ramanathan, V. and Y. Feng (2008) On avoiding dangerous anthropogenic interference with the climate system: Formidable challenges ahead. Proceedings of the National Academy of Sciences of the United States of America 105 (38): 14245-14250.

Raupach, M. R., G. Marland, et al. (2007) Global and regional drivers of accelerating CO_2 emissions. Proceedings of the National Academy of Sciences of the United States of America 104 (24): 10288-10293.

Ringwald, A. (2008) India. Renewable Energy Trends. Center for Social Markets (CSM) Discussion Paper Series. Kolkata, India.

Robins, N., R. Clover, C. Singh (2009) A Climate for Recovery. The colour of stimulus goes green. HSBC global research.

Schellnhuber, H. J. (2008) Global warming: Stop worrying, start panicking? Proceedings of the National Academy of Sciences of the United States of America 105 (38): 14239-14240.

Shukla, PR., S. Dhar, D. Mahapatra (2008) Low-carbon society scenarios for India. Climate Policy, Vol. 8:S156-76.

Smith, J.B., S.H. Schneider, et al. (2009) Assessing dangerous climate change through an update of the Intergovernmental Panel on Climate Change (IPCC) "reasons for concern". Proceedings of the National Academy of Sciences of the United States of America.

Spilimbergo, A, S. Symansky, O. Blanchard, and C. Cottarelli (2008) Fiscal policy for the crisis. IMF Staff Position Note SPN/08/01, Washington DC.

Stern, N. et al. (2007) The economics of climate change, Cambridge University Press, Cambridge, UK.

Stern, N. (2008) Key Elements of a Global Deal on Climate Change. The London School of Economics and Political Science, London.

Strbac, G. (2002) Quantifying the System Costs of Additional Renewables. Ilex Energy Consulting and University of Manchester, UK.

Süddeutsche Zeitung (2009) Die nächste Ölkrise kommt. Interview with Nobuo Tanaka, 27.02.2009.

UNCTAD (2009) Assessing the impact of the current financial and economic crisis on global FDI flows.

UNEP and New Energy Finance (2009) Global Trends in Sustainable Energy Investment 2008.

UNEP (2008) Public Finance Mechanisms to Mobilise Investment In Climate Change Mitigation.

UNEP (2009) A Global Green New Deal. Final report by the United Nations Environment Programme.

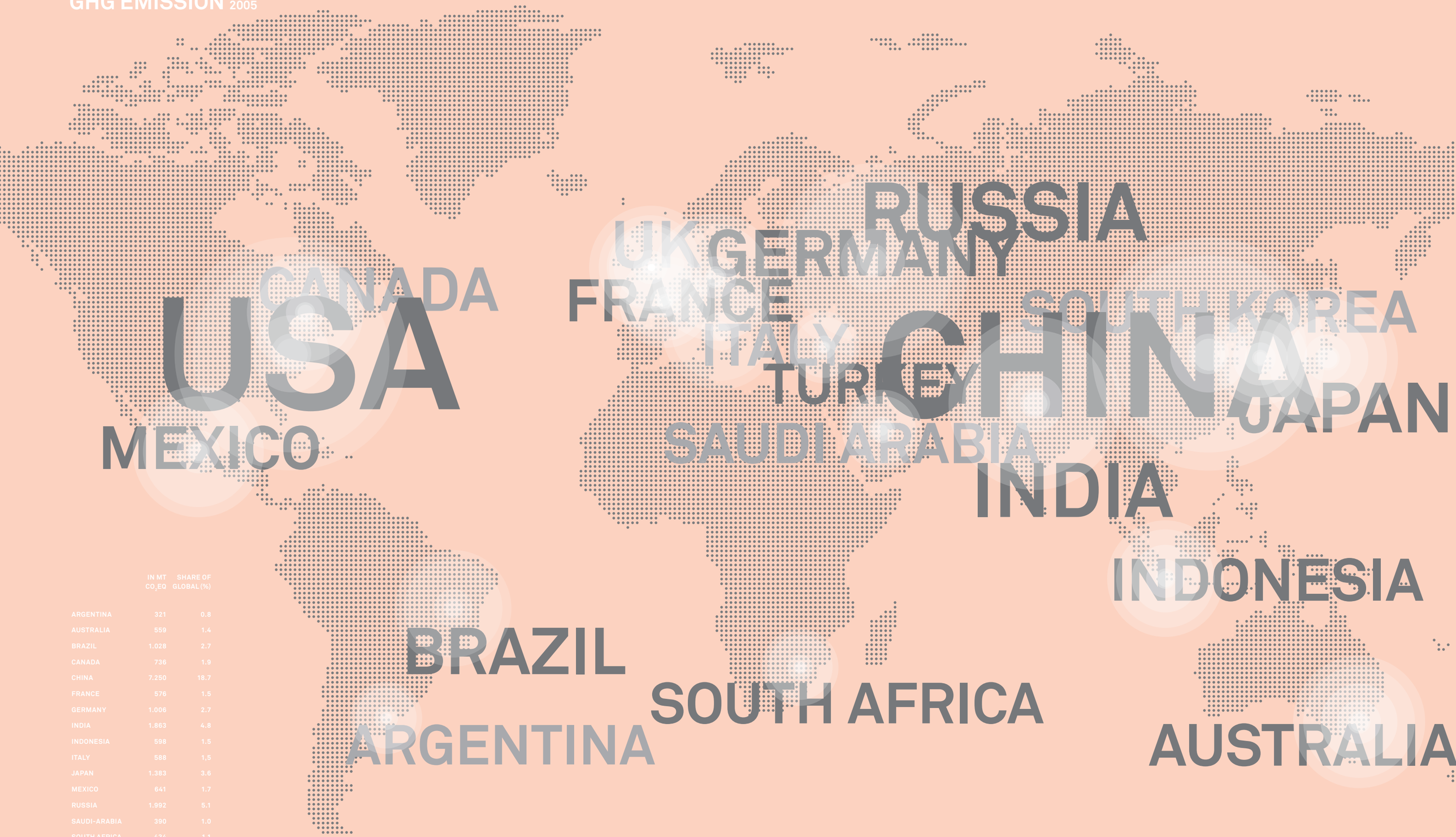
UNFCCC (2008) Investment and financial flows to address climate change: an update.

US DOE and NREL (2008) 20% Wind Energy by 2030 – Increasing Wind Energy's Contribution to U.S. Electricity Supply. US Department of Energy and National Renewable Energy Laboratory.

World Bank (2008) The Clean Technology Fund. World Bank, Washington DC, June 9, 2008.

WRI (2009) CAIT (Climate Analysis Indicators Tool) database of the World Resource Institute.

GHG EMISSION 2005



	IN MT CO_2EQ	SHARE OF GLOBAL (%)
ARGENTINA	321	0.8
AUSTRALIA	559	1.4
BRAZIL	1.028	2.7
CANADA	736	1.9
CHINA	7.250	18.7
FRANCE	576	1.5
GERMANY	1.006	2.7
INDIA	1.863	4.8
INDONESIA	598	1.5
ITALY	588	1,5
JAPAN	1.383	3.6
MEXICO	641	1.7
RUSSIA	1.992	5.1
SAUDI-ARABIA	390	1.0
SOUTH AFRICA	434	1.1
SOUTH KOREA	588	1.5
TURKEY	400	1.0
UNITED KINGDOM	683	2.7
UNITED STATES	7.098	18.3
G20 TOTAL	28.132	74.6
REST OF WORLD	10.594	26.4