Climates of Change: Sustainability Challenges for Enterprise

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India and climate change mitigation

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I. Introduction

While global warming can be argued to be a matter of urgency, it is also a long-horizon, protracted transformational challenge distinguished by a 'cascade of uncertainty', encompassing climate science, technology breakthroughs, and economic thresholds. The volatile (or fickle) economics can be appreciated within contemporary developments, for example, when the fluctuation in oil prices in 2008 is juxtaposed with the affordability of alternatives; petrol at US$4/gallon means that a hybrid petrol-electric car would pay for itself in 2–3 years, but at below US$2/gallon, the payback is 7–8 years. Since natural gas prices are tied to oil prices, the recent sharp decline in these prices has thrown into doubt the economics of forms of (cleaner/low-carbon-emitting) generation that compete with natural gas, including nuclear and renewables such as solar and wind.[1] An even more important backdrop for the goal of climate stabilization, is the current bleak outlook for the global economy; it is unclear whether the (OECD) constituency for pricing carbon (either through a direct levy or a cap-and-trade) will have the stomach to accept, when

[1] Price evolution of other commodities over the business cycle, on the other hand, has helped alternatives recently. For 25 years the cost of solar panels declined, sliding to US$3.15/ Watt-peak ($W_p$) by 2004. Then global demand soared, and the spot price of polysilicon, normally less than US$200/kg, jumped to more than US$450/kg, which pushed the price of solar panels to US$5/$W_p$. However, polysilicon manufacturers are bringing into production new capacities in 2009 (more than 50 companies have entered the market in the last 2 years); in addition, the global crisis and a severe slowdown in some key markets has taken its toll on demand, therefore spot prices of polysilicon have plunged and the price of solar panels has sunk to US$3/$W_p$, with more declines predicted.

economic activity and incomes are declining, permanent higher prices for energy sourced from hydro carbons.[2]

The consensus among climate scientists is that there are significant risks of a negative feedback from higher temperatures and concomitant catastrophic changes if global average temperatures rise by more than 1–2^{o}C. Atmospheric concentrations of carbon dioxide (CO_2) and other greenhouse gases (GHGs) are increasing rapidly, and are held largely responsible for increasing the earth's average surface temperature by 0.7^{o}C over the past century (IPCC, 2007*b*).[3] Levels of CO_2 have continued to increase during the past decade since the Kyoto treaty was agreed and they are now rising faster than even the worst-case scenarios from the Intergovernmental Panel on Climate Change (IPCC). In the meantime, the natural absorption of CO_2 by the world's forests and oceans has decreased according to scientists. Some scientists argue that the failure to curb emissions of CO_2, which are increasing at a rate of 1 per cent a year, has created the need for an emergency 'plan B' involving research, development, and possible implementation of a worldwide geoengineering strategy.

Recently, the fresh and favourably disposed US administration that took office in January 2009 has given impetus to the likelihood of a global agreement effective post-2012 to succeed the Kyoto Protocol, which was negotiated in 1997 and went into force in 2005.[4] Towards the end of 2008, the EU agreed (after much public haggling from the former East European bloc) on commitments for a 20 per cent reduction in emissions and to source 20 per cent of energy from renewable sources by the end of the second decade of this century.

The Bali Action Plan, which set the terms for long-term cooperative action for the post-2012 period, reiterated the equity principle of 'common but differentiated responsibilities' and emphasized the need for 'positive incentives for developing

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[2] The International Energy Agency (IEA) reckons that, even by 2030, coal, oil, and gas will satisfy up to 80 per cent of the world's energy demand.

[3] Another 0.6^{o}C increase is widely accepted as inevitable owing to the GHGs which have already been emitted.

[4] The Kyoto Protocol set a target for developed countries at about 5 per cent below the 1990 level of the six GHGs. Even this modest target will not be reached by any signatory according to data in Table A10 of the US Energy Information Administration's *International Energy Outlook 2008* (EIA, 2008*a*).

country Parties for the enhanced implementation of national mitigation strategies and adaptation action'. The UN Conference of the Parties (COP 15) in Copenhagen towards the end of 2009 could be decisive in determining the post-2012 policy scaffolding as well as the operational next steps and the associated institutional architecture.

The current state of play regarding global action on climate mitigation can be summarized as follows.

- The Kyoto Protocol emissions target for 2008–12 agreed by advanced countries will almost certainly not be met.
- Advanced (Annex 1) countries' emissions in recent years have increased in absolute terms and in *per capita* terms (Government of India—GoI, 2008*d*).
- Except for the flow of funds through the Clean Development Mechanism (CDM), advanced countries have done practically nothing to alleviate developing-country anxiety that they will not be helped financially—adequately in a predictable and sustainable manner—for meeting the (seriously) expensive twin challenges of mitigation and adaptation.
- The recent EU 20-20-20 commitment[5] may come to rely substantially on offsets from developing countries rather than actual reduction in emissions. (EU plans for combating global warming is reminiscent of Soviet planning—missed targets have spurred even more ambitious ones next time round!)
- Not much by way of material and durable outcomes can be gauged, in terms of emissions reduction from current levels, until 2020 or thereabouts.

Despite this unpromising beginning, there is now a growing consensus among governments that aggressive climate-change mitigation would be desirable, though they remain bitterly divided about how the associated burden should be shared.[6] India's position in climate negotiations, like that of most developing countries (DCs), has been largely negative. The Government of India has made a commitment not to allow the country's *per capita* emissions to rise above *per capita* emissions in the

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[5] The EU is committed to reducing its overall emissions to at least 20 per cent below 1990 levels and increasing the share of renewables in energy use to 20 per cent by 2020.

[6] The influential Stern Report (Stern, 2007) estimated the cost of mitigation to be around 1 per cent of global GDP. It has been cogently argued by Dieter Helm (ch. 2 in this volume) that this is an underestimate. Note also that the Stern Report does not allow for the important possibility that the shadow price of capital may be greater than unity.

advanced countries (ACs) (GoI, 2008*c*).[7] But this commitment, however honest and well-intentioned, is not credible, given India's unwillingness or refusal to join a treaty and take on internationally agreed binding targets.We argue below that India should reconsider its stance and negotiate to join a mitigation treaty, say in 2020, *if* it can negotiate a fair deal.

We take it for granted in this chapter that aggressive mitigation would be desirable from a global perspective.[8] An important India-specific point should be noted, however. India is more vulnerable to climate change than the USA, China, Russia, and, indeed, most other parts of the world (apart from Africa).[9] The losses would be particularly severe, possibly calamitous, if contingencies such as the drying up of North Indian rivers and disruption of monsoon rains came to pass. Consequently, India has a strong national interest in helping to secure a climate deal.

The plan for the rest of the chapter is as follows. Section II outlines the criteria that a global mitigation agreement would need to satisfy and explains the importance of cap-and-trade as the keystone of that agreement. Section III underscores the inescapability of ethics in determining the fair distribution of the costs of mitigation and argues that there is a strong moral case for all or most of the global costs being borne by the ACs. Section IV discusses the implications of some specific permit-allocation schemes under cap-and-trade, and reviews recent attempts to model them and the financial transfers that are implied. Section V reviews India's energy and emissions profile, with particular reference to the electricity sector, and highlights the country's energy (electricity) challenge. Furthermore, it draws attention to the fact that India is an efficient user of energy (in broad GDP terms), and is not shy of imposing taxes on energy. Section VI attempts, against the background of wide

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[7] In other words, if ACs reduce their *per capita* emissions to level *x*, India is committed not to allow its *per capita* emissions to exceed *x*. India's National Action Plan on Climate Change has succinctly documented changes in climate parameters in India, and the implications of these.

[8] Adaptation is an inadequate response on its own, because there are severe limitations to human ability to adapt to climate change. Our paper ignores the important topic of adaptation to climate change and the need for international assistance to DCs to help them adapt.

[9] See Nordhaus and Boyer (2000), Mendelsohn *et al*. (2006), and IMF (2008, ch. 4). More widely, research has indicated that tropical geography has a substantial negative impact on output density and output *per capita* compared to temperate regions (Sachs, 2001). Effects of higher temperature are also felt in growth (and not just level) of output; Dell *et al.* (2008) estimate a panel-data-based relationship based on historical temperature and precipitation readings and find that higher temperatures may reduce economic growth substantially in poor countries, but have little effect in rich countries.

dispersal of 'global/macro' estimates of abatement costs,[10] a bottom-up calculation for a key Indian sector—specifically, coal- and natural-gas-fired power generation—of the cost of abating carbon when carbon capture and sequestration (CCS) technology becomes available for deployment.[11] It also examines ways to finance CCS-inclusive investment in India's power sector through a mitigation treaty or via an expanded CDM. Section VII sets out our concluding thoughts on India's negotiating position in future climate bargaining.

II. Architecture and instruments of global mitigation policy

A global policy framework for mitigation must satisfy certain basic, widely agreed criteria. These are outlined below in an order that reflects expositional convenience, not intrinsic importance.

First, the framework should be global and comprehensive; in other words, it must cover all countries, or at least all significant emitters. The Kyoto agreement glaringly failed to do so since the USA did not join. In future agreements, participation by the USA and Europe will not be enough. The DCs need to be brought in because they are expected to contribute two-thirds of global emissions in the rest of this century in a business-as-usual (BAU) scenario. A comprehensive agreement is important for two further reasons. The first is the problem of 'leakage'. An agreement with partial coverage would lead to the migration of carbon-intensive industries to non-members, thereby negating the emissions reductions in participant countries. The second is that if significant trading partners were excluded, competitiveness concerns would erode the willingness of companies in the participating countries to comply with emissions targets.

The second criterion is that the framework should be efficient. To this end, it is important that it should operate predominantly through the market and strive to achieve a worldwide common price for emissions. This would lead both to cost-

[10] Prominent estimates include Stern (2007, 2008*b*) and the *World Energy Outlook* (WEO) (IEA, 2008*b*). Associated with the range of costs are diffused estimates of social marginal damages and optimal carbon taxes—see, for instance, IPCC (2007*b*), Nordhaus (2005), and Metcalf (2008).

[11] Globally, electricity generation has to be virtually decarbonized for meaningful progress by 2050.

effective emissions reductions and to appropriate price signals for the development of carbon-clean technology. But there remains an important choice: whether the common emissions price should be achieved by a global uniform carbon tax (CT) or a global cap-and-trade (CAT) system. We discuss this further below and conclude that CAT scores heavily over CT overall, and especially so from India's standpoint.

Third, the framework should be equitable. The major equity issue concerns burden-sharing. Mitigating global warming is costly. Distributing the cost fairly is important on moral grounds and also for obtaining participation and compliance by nation-states. It is not easy to specify or agree on what is 'fair', but that issue cannot be evaded. In practice, there will doubtless have to be a compromise between fairness and realism.

The fourth criterion is that the framework should be enforceable. It must have some meaningful disincentives for non-compliance.[12]

We discuss the equity criterion in some detail in the next two sections since it is critical in considering India's participation. In the rest of this section we focus on a major issue highlighted above. Should the centrepiece of the mitigation framework be a globally harmonized CT or a comprehensive global CAT system of emissions permits? A global uniform carbon price set at the right level would induce economic agents to carry abatement to the point where its social marginal cost equals its social marginal benefit. Under certain 'ideal' conditions, it does not matter for efficiency whether this uniform price is achieved by CT or CAT. The incentive to save energy and to innovate would be the same under the two alternatives, if CT is set at a level that induces the volume of emissions equal to the cap on the quantity of carbon emissions rights or permits under CAT. However, under non-ideal conditions, the effects of CT and CAT differ. Two of these qualifications are particularly important. The first relates to uncertainty, for example about the costs of abatement. If costs change, CT keeps the price of carbon unchanged but leaves the quantity of abatement undetermined. CAT fixes the quantity but leaves the price undetermined.[13] It may be thought that CAT is preferable in the climate-change

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[12] See Scott Barrett (ch. 4 in this volume) and Keohane and Raustiala (2008). The disincentives may eventually take the form of trade-related penalties. This is a complex issue, which we do not pursue in this chapter.

[13] A credible CAT system will require some safety-valve mechanism which prevents extreme fluctuations in permit prices. There are many suggestions for achieving this. (See IMF (2008,

context, since a quantity mistake would be especially dangerous. Then again, this consideration is not of great significance since the tax rate could be changed periodically. Certainty about the flow of emissions in a specific period is not critical, since what ultimately matters is the stock of emissions, and that changes slowly. The second 'non-ideal' consideration is that administrative costs, as well as corruption are likely to be higher with a CAT than with CT. On balance, CT would probably be preferable to CAT, if efficiency were the sole objective.

Efficiency is, however, only one desideratum of a good climate-change regime. The overwhelming superiority of CAT with respect to equity and compliance issues trumps any efficiency advantages that CT may possess. In a CAT system, trading of *any* initial allocation of permits would lead to economic efficiency. This extra degree of freedom means that the allocation can be chosen to deliver equity as well as to offer inducements for compliance. The implied transfers would take place automatically, as part and parcel of the working of the carbon trading market. With CT, a uniform international tax would have to be agreed—difficult enough, but only half the battle. Other aims, including equity, could only be achieved by explicit, visible, government-to-government transfers, which would be impossible politically to deliver.[14]

Since an equitable burden-sharing arrangement is the indispensable condition of Indian participation in a climate treaty, it is clear that India's interests would be much better served by CAT than CT. Luckily for India, it is probable, given the head start that CAT has had in Europe, that it will be 'the only game in town' in future climate negotiations.

III. Ethics of burden-sharing

A global climate-change agreement has to be equitable; it must spread the cost of supplying the public good of mitigation justly and fairly. Philosophers have argued since time immemorial about the concept of justice without agreeing on any

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ch. 4) and Cameron Hepburn—ch. 18 in this volume.) We assume throughout this paper that CAT systems incorporate this essential feature.

[14] Note that even in the domestic context, efficiency is not the sole criterion for choosing economic instruments. For example, corporations are taxed, despite the fact that personal income taxes would be more efficient, because the public finds the former more acceptable.

overarching theory. Even so, a strong moral case can be made for the proposition that the ACs should pay *all* the costs of global mitigation—'strong' in the sense that it can plausibly be based on several different and competing theories of justice.

We start with libertarianism. This is a non-consequentialist doctrine in which justice has nothing to do with outcomes or consequences. Libertarians care about the natural rights of individuals. Justice consists of nothing more or less than the protection of these rights. The right to property is a natural right and must not be violated. A person should not be deprived of property that she justly holds. Any holding of property is just that is acquired by just acquisition or transfer. A transfer is just if it is voluntary, not coercive. The definition of just initial acquisition is more complex since, as the progenitor of libertarianism John Locke put it, the 'earth and its contents belong to mankind in commons'. Common property can be justly converted into private property by the addition of labour, provided, to quote Locke again, 'enough and as good is left for others'. Acquisition of property is unjust if the Lockean proviso is not fulfilled. It then follows that corrective justice requires restitution or compensation.

The application of this theory to the climate-change problem is that the finite safe capacity of the atmosphere to absorb greenhouse gases is a common resource that belongs to all human beings but was 'expropriated' in large part by the ACs. The DCs deserve compensation for that, not as a matter of charity but as a matter of justice. It is what they are *owed*. The above argument for compensation does, however, have a major weakness. This is that the perpetrators of the expropriation acted under the impression that the atmosphere was an infinite resource. They could not even be accused of negligence because the relevant scientific knowledge did not exist. Moreover, if the perpetrators were culpable, they are long since dead and gone. It may be unjust to visit their sins on their descendants, even if they could be identified. These objections significantly weaken the claim that *past* expropriation constitutes a ground for just compensation.[15] Even so, 'equal *per capita* emissions rights' remains a morally appealing principle in considering the just *future* allocation of carbon space between individuals (and countries).

The strength of libertarianism is that it appeals to the moral intuition that cause, history, and process are important. But it ignores outcomes, consequences, and

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[15] But they do not, in our judgement, refute the claim entirely.

‘end-states’ entirely. Even extreme poverty would not count as a ground for just redistribution if liberty rights have not been violated. Many people would find this morally repugnant. Some other moral theories take the view that large inequalities of wealth are unjust, even if they have arisen out of entirely legitimate processes. We consider below two major strands of ethical thinking which reach egalitarian conclusions. The first is utilitarianism, a consequentialist ethical doctrine in which the rightness of actions depends solely on their consequences for individual ‘utilities’ or satisfactions. A right action is simply that which maximizes the sum of individual utilities. Utilitarianism is in some ways an attractive doctrine for public policy: it is an appealing notion that policy should promote overall satisfaction, in which each individual’s satisfaction counts equally. Utilitarianism is radically egalitarian if we assume that income has diminishing marginal utility and that people are alike in their tastes and preferences. It then follows that an extra dollar is worth more to a poor person than to a rich person. The logic of this argument implies that incomes should be redistributed from the rich to the poor, unless inequality can be justified as helpful for increasing the sum-total of utility—due to incentive effects, say.

The proviso about incentives is indicative of the point that utilitarianism is not foundationally egalitarian. It would sanction redistribution from the poor to the rich if that could be shown to increase total utility—say because the rich were better converters of income into personal utility.[16] However, when modest redistributions from the very rich to the very poor are the issue, such arguments are unpersuasive. Plainly, utilitarians would be in favour of the ACs shouldering the whole burden of climate-change mitigation.

We have noted that utilitarianism offers only indirect support for redistribution from rich to poor. Egalitarian moral theories, which underlie the use of ‘ability to pay’ criteria in public finance, do so directly. Some of these are based on non-libertarian rights. It has been argued, for example, that individuals’ natural rights include not only negative rights to life, liberty, and property, but also some positive rights to a minimum standard of living. A theory of justice based on positive rights can, however, be criticized on the ground that it is unclear whose duty it is to honour these rights.

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[16] Utilitarianism also suffers from another crucial defect. It has no place at all for natural rights. This offends against some powerful moral intuitions. For example, it would be wrong to kill an innocent man who is widely thought to be guilty, even if we suppose that it would increase total utility because of its deterrent effect. Many people, therefore, find undiluted utilitarianism an unacceptable doctrine.

But this charge is not persuasive. For example, in the case of climate-change mitigation, the duty-bearers are quite plausibly the (governments of) ACs. Given the huge incidence of abject poverty in the DCs, governments of ACs have a moral obligation to bear the cost of climate-change mitigation as well as the power to discharge that obligation.

An important strand of egalitarianism locates the grounds for distributive justice in social relations—for example, in a hypothetical social contract. John Rawls's influential theory envisages a contract set up under a hypothetical 'veil of ignorance' in which participants do not know anything about themselves. (The 'veil of ignorance' is a device to ensure impartiality.) Rawls argues that the veiled contractors would choose a social framework in which would be enshrined a principle of individual liberty, followed by a principle of distributive justice, viz. 'the difference principle', stipulating that benefits and costs be distributed so as to maximize the welfare of the worst-off individuals. The theory is egalitarian but not equalitarian; inequalities would be permitted if they were to the advantage of the worst-off. Despite this proviso, it is obvious that the theory would endorse ACs defraying the entire cost of global mitigation. The world's worst-off individuals are mostly to be found in DCs and it is highly implausible that their lot would be improved if some or all of the burden of mitigation was borne by the DCs rather than the ACs.

We must note, however, that Rawls himself did not think of his theory in cosmopolitan terms. In his view the concept of justice makes sense only in a 'scheme of cooperation', such as a nation-state, and the world as a whole does not satisfy this description. But others have extended the Rawlsian theory to the world level by postulating a hypothetical contract that covers all human beings, an extension that yields a 'global difference principle'.

The preceding paragraph alerts us to an important question which was begged in the above discussion: what is the *domain* of justice? Is it the whole world or the nation-state? Strictly speaking, utilitarian and natural-rights-based theories have cosmopolitan premises, which regard national boundaries as morally arbitrary. Just as justice between individuals must ignore distinctions of colour, race, or sex, it must ignore distinctions of nationality. Nevertheless, despite obvious inconsistency, the dominant moral perspectives have been nation- or state-centric. Utilitarians, libertarians, and egalitarians have all, in practice, limited the domain of justice largely to the nation-state. Globalization, however, powerfully challenges this parochial standpoint. The fact and the perception of global interconnectedness, of which climate change is an archetypical example, has shown that the world should be regarded for many important purposes as one community. Our erstwhile values were the product of circumstances in which the atmosphere could be thought of as an unlimited resource. These circumstances no longer obtain, and a purely nationalist ethical perspective no longer makes sense.[17] The minimum requisite change to our ethical perspectives is to move towards a weakly cosmopolitan position, viz. compatriots have priority but there are some (though weaker) duties of justice towards non-compatriots. Such a moral outlook is sufficient to reach the conclusion that the ACs should shoulder the whole burden of global climate-change mitigation.[18,19]

IV. Allocation of emissions permits

We have seen in section II that global CAT would achieve efficiency, whatever the initial distribution of emissions permits. That leaves the vital issue of how to allocate permits in a manner that satisfies equity criteria but is also realistic.[20]

Given a global cap, the boundaries of allocation can be established fairly easily. One extreme is to allocate permits on a *status quo* basis; that is, either in proportion to current emissions or to emissions in, say, 1990. This alternative can be dismissed as thoroughly unjust. It offends against every moral principle discussed in section III. DCs could not be expected to accept such a blatantly unfair scheme. The other extreme is to allocate *all* permits to DCs. This would imply that ACs would have to

[17] Values cannot be logically derived from facts, but a change in the facts may constitute a strong reason for adopting or abandoning certain values. For example, the value judgement that ‘people should be allowed to wear any clothes they like’ may be abandoned if striped shirts begin to cause cancer in the eye of the beholder.

[18] Note that this is a minimal interpretation of the obligations of the ACs. The theories outlined above can support a case for large income transfers to DCs, well beyond covering their mitigation costs. *A fortiori*, there is a strong moral case for the position we have taken in the context of climate change.

[19] An important objection to the case made above should be noted here. In practice, the redistribution of income implied in our conclusion would be from rich to poor states, not directly from rich to poor people. How can we be sure that poor people in poor states would actually benefit? Some faith in the benevolence of states is undoubtedly required.

[20] For a discussion of this issue, which has a different slant from ours, see Posner and Sunstein (2008).

buy permits for all their emissions from DCs, which, in turn, would necessitate a large transfer from ACs to DCs, well in excess of what the latter would need to compensate them for the costs imposed on them by a high carbon price. Though this could certainly be justified on the basis of the theories outlined above, it is unrealistic in a world in which even the 0.7 per cent of GDP target for foreign aid remains massively under-fulfilled. The allocation of permits between the above two limits will be determined by bargaining and negotiation in which both moral considerations and naked self-interest would play their parts.

Some intermediate allocative schemes deserve consideration. The first is an allocation that is based on equal *per capita* emissions.[21] This allocation would have the appealing moral feature that it would give every person on earth the same emissions rights over the atmospheric global commons. (Of course, the rights would in practice have to be given to states, not persons, but that concession to reality is unavoidable.) This allocative principle would in practice also have the advantage, broadly speaking, of favouring poor people worldwide since a large majority of them inhabit populous countries. But this is not invariably true; for example, the USA is a relatively populous country.[22] This last point suggests adoption of a criterion which is more explicitly in tune with egalitarian moral theories. Permits could be distributed inverse proportion to *per capita* income.[23] This would be highly redistributive towards poor countries.[24]

Both the equal *per capita* emissions and inverse *per capita* income criteria would doubtless be criticized in the obvious quarters for ‘overcompensating’ DCs in the sense of rewarding them more than strictly required to pay for the costs inflicted by a globally appropriate carbon price. This suggests another criterion for permit allocation, viz. to allocate just enough permits to each DC to prevent the estimated

[21] Thus, consider a world of two countries, USA and India. If India’s population were four times that of the USA, India would be allocated four-fifths of the world cap of permits.

[22] It has been argued by some that this criterion would also militate against long-run efficiency because it would create a perverse incentive to pursue high-fertility policies. This is implausible. There are many good reasons for countries not to pursue policies to maximize the size of the population.

[23] Thus, in a two-country world in which the US *per capita* income at purchasing power parity is 12 times that in India, India would receive approximately 92.3 per cent of permits, the USA 7.7 per cent.

[24] Like the equal *per capita* emissions criterion, this one, too, could be criticized on *ex ante* efficiency grounds, since it would create an incentive to remain poor. Again, implausible!

welfare loss it would suffer from climate mitigation.[25] We are strongly attracted to this criterion as a reasonable compromise between fairness to DCs and acceptability to ACs. The criterion looks complex but has been implemented in a quantitative model, as we see below.

In practice, the politics of negotiating permit allocation will involve many other considerations: (i) countries' bargaining positions will depend on the benefits to them of avoiding climate change. The less vulnerable they are, the stronger their bargaining position, since they would lose less by walking away from a deal; (ii) bargaining positions will also depend on the strength of public opinion in different countries in favour of mitigation; (iii) ACs can be expected to resist an allocation of targets and permits that departs very drastically and quickly from the *status quo*; this is not unreasonable, perhaps not even ethically. The reason is that ACs' high carbon-dependency could imply significant dislocation of their economies, though they could soften the blow by making the transfers required to buy permits. They would doubtless also wish to minimize transfers. A compromise is unavoidable. The permit-allocation formula could incorporate weights on population and *per capita* income that rise over time gradually, not abruptly; other constraints could also be built in, such as a cap on the loss suffered by any AC both in present-value terms and in any given year.[26]

Where does India stand in the negotiation game? Its moral position is strong since India is a heavily populated country with a low *per capita* income. Moreover, its expected growth rate is high, which means that it stands to lose a lot in the short run by sacrificing carbon-intensive development (unless it is compensated). All these points count heavily according to any respectable moral theory. Nevertheless, the importance of the high moral ground should not be exaggerated. India cannot expect to succeed in securing an allocation formula based purely on population and *per*

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[25] Needless to add, this is a *gross* loss. There need be no net loss: indeed, there would, for most countries, be net gain because mitigation will bring benefits in due course. In principle, equitable allocation of permits should also allow for the differential eventual gross benefits that countries would enjoy. But this is a counsel of perfection and would introduce a large additional layer of complexity to the allocation decisions.

[26] It would be desirable, however, to specify the targets not, as currently done, on the basis of production-associated emissions, but in terms of consumption-associated emissions. The former would be unwarrantedly favourable to the ACs since they have achieved some of their 'progress' in reducing emissions so far by outsourcing the production of emissions to DCs (see Helm, ch. 2).

capita income, because India's high vulnerability to climate change weakens its bargaining position.

Any bargaining would evidently have to be based on rough estimates of gains and losses to countries, given different assumed permit-allocation patterns. Such calculations may seem incredibly complicated but, in fact, there are several models around which have carried them out. The modelling strategy is straightforward. Two basic components are: the time profile of the global cap, and the global cost curve for mitigation, built up from the cost curves of constituent countries. The intersection of the two determines the equilibrium price of carbon and the marginal cost of mitigation. The third basic component is the allocation of permits. Given the carbon price and the permit allocation, each country is a buyer or seller of permits depending upon whether its marginal costs are higher or lower than the carbon price. The solution of the model yields the extent of carbon trading and the implied financing flows. Naturally the solution is heavily dependent on the shape and position of the global cost curve, which in turn depends on the assumptions made about technical progress. To this basic structure can be added various constraints that the solution has to satisfy.

We draw attention to three interesting modelling attempts, viz. Jacoby *et al*. (2008), Frankel (2008), and the WEO (IEA, 2008*b*). The Jacoby *et al*. model shows the implications of seven alternative schemes of permit allocation. India is explicitly included as one of the model's regions. Of the seven alternatives, six are of particular interest:

(i) a *status quo* allocation as of 2000, which is reduced over time up to 2050. In 2050, ACs', DCs', and global emissions targets would be, respectively, 30, 70, and 50 per cent of the 2000 baseline;

(ii) an allocation based on *per capita* emissions in 2000;

(iii) an allocation based on (the inverse of) *per capita* GDP in 2000;

(iv) an allocation (endogenously determined by the model) which would provide full compensation to DCs for the welfare cost of achieving the global target of 50 per cent emissions reduction by 2050, with the additional constraint that ACs are given equal amounts of permits as a proportion of their 2000 emissions;

(v) the same as (iv) but with a different additional constraint, specifically, ACs bear equal percentage costs in terms of GDP;

(vi) an allocation (endogenously determined by the model) such that compensation is paid to ensure that no DC's cost exceeds 3 per cent of GDP, with ACs given equal permits as a percentage of their 2000 allocations.

Allowance allocations, welfare effects, net transfers, and CO_2 price in the Jacoby *et al.* model for the USA and India for alternatives (i)–(v) in 2020 and 2050 are shown in Table 1. (Alternative (vi) is not presented since the transfers implied by it are not given in the Jacoby *et al*. paper, although it is clear that they would be smaller than those in alternatives (iv) and (v).) The numbers confirm our earlier surmises. Alternatives (ii), (iii), and (iv) score heavily over (i) from India's (and more generally the DCs') perspective but they involve significantly higher transfers than current flows of foreign aid. In addition, two other findings are notable. First, the *status quo* allocation that tapers down to 30/70 is, despite appearances, *not* favourable to India, which would receive negligible transfers and suffer high welfare costs. This is the result of India's expected high growth and hence its rapidly growing emissions under BAU. (A 70 per cent target for India in 2050 relative to 2000 emissions implies a target of about 25 per cent relative to BAU in 2050.) It would be unwise of India to accept a 30/70 target, or similar targets currently being bandied about. Second, since alternatives (ii) and (iii) would be unacceptable to ACs, it is interesting to observe that alternatives (iv), (v), and (vi), which are geared to keeping the welfare cost in DCs down to zero, involve much smaller welfare costs and outward transfers for the USA, and the ACs more generally, than (ii) and (iii).

Table 1: Effects of alternative allocation schemes in 2020 and (2050)

	(i) 30/70		(ii) Population-based		(iii) GDP-based		(iv) Full compensation (*a*)		(v) Full compensation (*b*)	
	USA	India	USA	India	USA	India	USA	India	USA	India
Welfare effect (% of GDP)	–0.1 (–2.6)	–4.9 (–11.4)	–2.8 (–5.5)	20.9 (21.0)	–3.9 (–7.2)	39.0 (48.9)	–1.3 (–7.4)	0.0 (0.0)	–1.9 (–9.4)	0.0 (0.0)
Net transfer (US$ billion)	–30.3 (–179.6)	10.1 (14.7)	–368.7 (–668.8)	232.7 (513.9)	–483.5 (–1,024.0)	439.7 (1,056.3)	–196.7 (–1,239.4)	51.8 (176.4)	–264.5 (–1,239.4)	52.3 (189.5)
Allowance allocation (2000 emissions = 100)	80 (30)	98 (70)	20.5 (11.4)	265.4 (147.1)	1.7 (0.9)	405.2 (224.6)	49.3 (–8.3)	127.6 (93.3)	37.3 (–22.5)	129.5 (93.5)
CO_2e price (approx.) (US$/t$Co_2$e)	75 (250)	75 (250)	75 (260)	75 (260)	75 (270)	75 (270)	n.a. n.a.	n.a. n.a	75 (270)	75 (270)

Source: Jacoby *et al*. (2008).

We now turn to the Frankel model. This is explicitly intended to incorporate politically realistic constraints on the allocation of permits. The allocation formula allows for both AC and DC concerns. On the one hand, it gives significant weight to current emissions in the immediate future, thus protecting the ACs against a sudden and draconian reduction in emissions (or a sudden and large increase in transfers). On the other hand, it also incorporates rising weights over time for population and *per capita* income. The DCs agree immediately to quantitative targets but in the first few decades they merely copy their BAU paths. The DCs are not expected to reduce emissions below BAU until they cross certain income thresholds. Other realistic restrictions in the model include the requirement that welfare losses for each country, intertemporal as well as in any single year, should not exceed specified limits. *Per capita* emissions of ACs and DCs do converge, but only towards the end of the twenty-first century.

The solution of the model shows that the above path is feasible. We focus on the numbers for the USA and South Asia (Table 2). (Unfortunately, the model does not include India as a separate region.)

Table 2: Emissions targets and economic costs

	2010		**2050**		**2100**	
	USA	**S. Asia**	**USA**	**S. Asia**	**USA**	**S. Asia**
Emissions target 1990 = 1	1.30	2.04	0.42	7.33	0.01	3.62
Emission target *per capita* (tons of C)	5.96	0.25	1.51	0.63	0.03	0.32
Approximate economic cost (% of GDP)	Negative	Negative	1.00	–1.00	Small positive	Small negative

Source: Frankel (2008).

For the USA, target emissions relative to 1990 as well as *per capita* emissions fall sharply from 2010 to 2050. However, for South Asia they rise, since they follow the BAU path. From 2050 to 2100, the reductions in the USA are extremely severe; there are cuts in South Asia, too, but not quite so fierce.[27] There are negligible welfare costs for both USA and South Asia

[27] The related time-path of the world real price of CO_2 is intuitively plausible. In 2020, the price is at the lower end of extant estimates in the literature at US$30/tonne, it is then flat for a few decades due to the assumption that DCs do not undertake major emissions cut before 2040, and subsequently climbs rapidly as targets begin to bite for DCs; the price of CO_2 crosses US$100/tonne by 2050, and levels off toward the end of the century at about US$700/tonne.

at the start; thereafter, the USA shows moderate losses, but South Asia gains somewhat as a result of sale of permits. A significant downside is that Frankel's algorithm delivers concentration stabilization of 500 parts per million (ppm) of CO_2 only in the last quarter of the century (and not by 2050, as in most other frameworks), which some mitigation enthusiasts may consider as too late.

Finally, the WEO in its latest report (IEA, 2008*b*) examines—for a shorter horizon compared to other studies—the implications of a reduction in energy-related CO_2 emissions under different *ad hoc* rules of allowance allocations. For the goal of a 10 per cent reduction in global emissions by 2020 (relative to WEO's reference scenario), Table 3 provides region-wise (including for India) calculations for three alternative allocation mechanisms—specifically, equal *per capita*, current level of emissions, and current GDP. For allowances based on a *per capita* basis, national allocations for many non-OECD countries, not surprisingly, will be substantially higher than their current and projected BAU emissions. Since the surplus countries would be able to generate income by trading the excess allowances, there is scope for substantial financial flows to developing economies. Countries in Africa and Latin America gain. So does India, which stands to garner as much as US$134 billion (about 5 per cent of GDP) in 2020.[28] In contrast, if the allocation is relative to current emissions or current GDP, then India will face a shortfall and have to purchase allowances worth around US$30 billion in 2020.

The results of these models are only as good as their assumptions, and they have to be taken with several pinches of salt. They suffice to show, however, that the models can accommodate realistic restrictions and produce solutions that may potentially be acceptable to all sides. Although permit allocations instantly geared to equal *per capita* emissions or permanently geared to current emissions would doubtless be unacceptable to ACs and DCs respectively, there is a large grey area between these boundaries which would be amenable to bargaining and negotiation.

[28] Note that the large inward transfer associated with an equitable allocation for India could create a 'Dutch disease' problem characterized by real exchange-rate appreciation and contraction of the tradable sector. This would be a challenge for macroeconomic policy, albeit not an insuperable one.

Table 3: Change in 2020 of energy-related CO_2 emissions and associated financial flows under different allocation rules to achieve a 10 per cent reduction in emissions relative to the reference scenario

Region/country	Based on current emissions			Based on equal *per capita* emissions			Relative to current GDP		
	Emissions (Gt)	Change *vis-à-vis* reference scenario (Gt)	Potential financial flows (US$ billion)	Emissions (Gt)	Change *vis-à-vis* reference scenario (Gt)	Potential financial flows (US$ billion)	Emissions (Gt)	Change *vis-à-vis* reference scenario (Gt)	Potential financial flows (US$ billion)
USA	6.64	+0.87	+34.8	1.44	–4.33	–173.2	6.87	+1.10	+44.0
EU	4.62	+0.67	+26.8	2.09	–1.86	–74.4	6.99	+3.04	+121.6
Japan	1.41	+0.26	+10.6	0.52	–0.63	–25.2	2.13	+0.98	+39.2
Other OECD	2.32	–0.12	–4.9	1.24	–1.19	–22.8	3.00	+0.56	+22.4
China	6.6	–3.40	–13.6	5.90	–4.10	–164.0	3.30	–6.7	–268.0
India	1.47	–0.72	–28.8	5.54	+3.35	+134.0	1.40	–0.79	–31.6
Africa	0.99	–0.09	–3.5	5.16	+4.08	+163.2	1.18	+0.10	+4.0
Russia	1.84	–0.08	–3.2	0.56	–1.36	–54.4	0.98	–0.94	–37.6
Middle East	1.53	–0.56	–22.6	1.02	–1.07	–42.8	1.05	–1.04	–41.6
Latin America	1.24	–0.14	–5.6	2.42	+3.80	+152.0	1.38	—	—
Total change from 2020 reference scenario (in Gt)		–3.31			–3.31			–3.69	
(Change in per cent)		(–10%)			(–10%)			(–10%)	

Source: Calculations based on Tables 16.2 and 17.2, and a price of US$40/tonne of CO_2 in 2020 (all from WEO (IEA, 2008*b*)).

V. Under-provision of energy in India

Asking India (or, for that matter, DCs more generally) to ‘contribute’ towards emissions reduction, essentially by making energy more expensive (in the absence of financial compensation) is hardly tenable from any conventional dimension. Consider the following.

- The Indian power sector has about 160,000 MW of installed capacity, but its *per capita* electricity consumption is still among the lowest globally—for example, about a third of China’s (see Patel and Bhattacharya (2008) for a recent analysis of India’s power sector).
- 44 per cent of the population is without access to electricity (GoI, 2008*c*).
- Nationwide shortage of electricity has been steadily rising; during 2008/09 (April–January) the average shortfall between demand and supply was 11 per cent, and the peak shortage in January was 12.3 per cent.[29]
- Over 70 per cent of the energy requirement of households (mainly for cooking) is satisfied by firewood and dung cake, which result in eye infections and respiratory problems linked with indoor pollution (GoI, 2006); the large health externality (not to mention, the resultant output loss) may warrant a household subsidy for fuel stoves and for liquefied petroleum gas (LPG) and kerosene.[30]
- India consumes 16m Btu of primary energy *per capita*/year compared to 56m Btu in China, 335m Btu in the USA, and a world average of 72m Btu.
- CO_2 intensity in tonnes/million 2000 US$ GDP is 287 for India, 544 for the USA, 693 for China, and 383 for OECD Europe (EIA, 2008*b*). Over the past decade, India’s energy intensity has been declining by 4–5 per cent/year.
- India imposes significant energy taxes.

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[29] *Source*: http://www.cea.nic.in/ (The Indian fiscal year is 1 April–31 March.)

[30] Black carbon and organic carbon emissions from kerosene and LPG stoves have been estimated to be lower than from those from biofuel stoves by a factor of 3–50; combustion of biofuels is a potentially significant source of atmospheric black carbon and associated climatic effects in South Asia (Venkataraman *et al.*, 2005).

Not only is India's recent emissions performance creditable, but even the BAU scenario for the period up to 2030, summarized in Appendix Tables A1(*a*), A1(*b*), A2(*a*), and A2(*b*), makes it clear that India will continue to be a relatively frugal consumer of energy on both a *per capita* and an output basis.[31]

There is a perception that energy consumption in India is (highly) subsidized (IEA, 2008*b*). Concurrently, availability of power at a reasonable price is often cited as the most important constraint to India's (industrial) growth prospects by foreign and domestic investors. While subsidies constitute one part of the fiscal overlay on the energy sector, taxes are another. We aggregated all energy-related taxes (that we could figure out) and compared the magnitude with (actual and implicit) subsidies on petroleum products, natural gas, electricity, and coal. It turns out that taxes on energy account for over a quarter of national indirect tax revenue, and close to a fifth of total (direct and indirect) tax revenue. Overall, the hydrocarbon sector is taxed even after deducting subsidies, albeit with sub-segments treated differently (see Table 4). In net terms, the petroleum sector is taxed most heavily, electricity consumers enjoy the largest subsidy,[32] and coal consumption is not subsidized. Against this background, any questioning of India's effort towards curtailing emissions would need to recognize, *inter alia*, the contribution to 'net carbon taxes' of present (and past), often heavy, taxation of energy (see Nordhaus (2005) and Frankel (2007)). A rough-and-ready calculation indicates that the net taxation on petroleum entails an 'emissions tax' of about US$49/tonne of CO_2 emitted from this source in 2007. On the other hand, emissions from coal are (implicitly) 'taxed' at around one dollar per tonne, and for the energy sector as whole, emissions (on average) are 'taxed' at about US$6/tonne.[33]

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[31] It is instructive that even the benchmark (reference) multi-decadal scenarios for energy-related national and global emissions put out by credible sources differ significantly. For instance, the global BAU estimate for 2030 is lower by 1.75 Gt in WEO (IEA, 2008*b*) compared to the Energy Information Administration (EIA)/International Energy Outlook (IEO) projection, also made in 2008 (EIA, 2008*b*). On the other hand, for India the estimate for 2020 in WEO is larger by 1 Gt. The EIA assumes, for India, an annual GDP growth rate of 5.8 per cent (2005–30), while WEO deploys 6.4 per cent (2006–30).

[32] The subsidy has been declining in recent years.

[33] These 'tax' calculations should, of course, be treated with caution for obvious reasons. Indian CO_2 emissions for 2007 are taken to be 4 per cent higher than the figure for 2006 reported in WEO (IEA, 2008*b*), and the net taxation figures are from Table 4.

Table 4: Estimates of energy-sector tax and subsidy aggregates (Rs crores)

	2006/7	2007/8
Taxes		
Petroleum related:		
Central excise duty	58,821	54,769
State sales tax	53,949	55,677
Customs duty	10,043	12,625
Other centre taxes	4,822	12,569
Other state taxes	6,006	6,789
Tax and duty on electricity	8,559	9,052
Natural gas related [a]	2,400	2,500
Coal related [b]	3,025	3,500
Total	**147,625**	**157,481**
Subsidies		
Petroleum	48,000	73,000
Electricity	34,800	34,400
Natural gas [a]	16,800	18,700
Coal [b]	0	0
Total	**99,600**	**126,100**

Notes: 1 crore = 10 million rupees. [a] Domestic production of natural gas accounts for about ¾ of total consumption. India consumed in 2006/7 and 2007/8, respectively, 31,368 million metric standard cubic metres (MMSCM) and 34,328 MMSCM of gas. The (weighted) average ex-terminal price of gas sold in India is estimated at US$3.1/ million British thermal units (MMBtu) (2006/7) and US$3.3/MMBtu (2007/8); the average international price—using the Henry Hub Index—is US$6.6 (2006/7) and US$7.3 (2007/8). For estimating the indirect tax burden on natural gas consumption, we have used a composite/weighted average rate of 16.5 per cent (comprising of state sales tax, central sales tax, and duty on imports, but excluding service tax on transportation and regasification services).
[b] India produces about 450m tonnes of coal. The average price of coal supplied to the National Thermal Power Corporation (NTPC) in 2007/8 is estimated at Rs. 1,800/tonne (about US $45/tonne), which we have assumed for all customers (NTPC consumes 27 per cent of domestic coal production, and about 70 per cent of domestic production is used for electricity generation). The average calorific value of Indian coal is 3,500–4,000 kcal/kg, which is comparable to low-quality Indonesian coal (4,200 kcal/kg at a price of US$30–38/tonne for 2007/8). The average price of coal supplied to NTPC in 2006/7 is estimated at Rs1,750/tonne (about US$39/tonne); and the average price of low quality Indonesian coal in 2006/7 was about US$28–31.5/tonne. Coal-related tax revenue reported in the table is an (interpolated) estimate comprised only of royalty payments by national coal companies, and is therefore an underestimate since the figure does not include mining-related cesses and taxes (such as entry tax, among others) imposed by various state governments at diverse rates, as also customs duty by the central government on imported non-coking coal.
Sources: Union budget documents at http://finmin.nic.in/, GoI (2008*a*,*b*), http://ppac.org.in/ and Ministry of Coal website.

VI. Inescapability of coal-generated electricity

(i) Coal is the key: unrivalled intersection of abundance, affordability, and energy security

Given the legacy of the extant energy profile, overall energy demand growth in emerging markets, and broad availability and evolution of prices, it is accepted that despite increasing use of renewables, fossil fuels will continue to comprise a significant part of the global energy mix until 2030 (even for developed blocs such as Europe and the USA).[34] The single largest fossil fuel in the energy mix is coal, at 40 per cent of global energy consumption. Coal has major attributes: (i) it is the lowest-cost fuel source for base-load electricity generation; and (ii) coal endowments are widely distributed around the world, hence, it supports the national energy security objectives of a number of large economies, including India.[35] Coal accounts for three-quarters of India's hydrocarbon reserves, and is the most abundant domestically available primary energy resource other than thorium and solar insolation.[36,37]

(ii) Carbon capture and sequestration (CCS) abatement potential

Coal's contribution to total global CO_2 emissions declined to about 37 per cent early this decade (compared to 39 per cent in 1990), but is projected to exceed 40 per cent by 2030. In all scenarios, a major potential contributor to global emissions reduction by 2050 is the curtailment in CO_2 emissions from coal to half or less of today's level and to one-sixth or less of BAU projections.[38] CCS is the only known technology for capturing emissions from CO_2—not only from fossil-fuel power plants (coal and natural gas), but also from other industrial

[34] With predicted increase in electricity demand—almost double by 2030 to 35.4 TWh—fossil fuel-based generation is also expected to double by this date, and the concomitant share of coal in electricity generation will increase from 40 to 45 per cent. (A 500 MW coal-fired power plant emits about 3m tonnes of CO_2 annually.)

[35] Fossil sources provide 80 per cent of global energy. Of the electricity generated in the USA, 50 per cent is from coal; in 2007 coal-based power generators in the USA emitted 1.98 Gt of CO_2 while generating 2.02 gWhr (EIA, 2008*a*).

[36] High-quality coal imports by India are forecast to be 120–770m tonnes by 2031/2 (GoI, 2006).

[37] While the recent civil nuclear agreements with various countries can facilitate huge investments in nuclear energy, the Indian government envisages a modest addition of 3,400 MW during the 11th Plan period (2007/8–2011/12). The high initial cost on account of up-front capital imports, as also the obvious implementation problems of a large-scale rollout in a sensitive sector (owing to concerns over security and safety) are plausible drivers for the government's cautious approach.

[38] There is a view (recently espoused, most notably, in *The Economist*, 14–20 March 2009) that CCS is unlikely to become a viable option as an instrument for climate-change mitigation.

processes such as steel, cement, and refining; for most of these latter activities, at current knowledge, CO_2 cannot be avoided as a by-product.[39]

While many of the component technologies of CCS are relatively mature, to date there are no fully integrated power-generation-related commercial-scale CCS projects in operation (to the best of our knowledge). However, current knowledge gaps appear not to cast doubt on the essential feasibility of CCS (Deutch and Moniz, 2007). According to IPCC's 2005 report on CCS, the economic potential of CCS would be 200–2,200 Gt of CO_2, or 15–55 per cent of the cumulative global mitigation effort to 2100, under likely GHG stabilization scenarios of between 450 and 750 ppm, in a least-cost portfolio of mitigation options.

(iii) CCS is very expensive

CCS in the context of coal necessitates integration of coal combustion and conversion technologies to CO_2 capture and storage. It also entails transportation of CO_2 produced at the coal-fired plant to the injection point at the reservoir site (onshore or offshore). In comparison to a *status quo* thermal power plant, CCS adds four supplementary costs: (i) installation of capture equipment; (ii) powering the capture process, which results in additional fuel use;[40] (iii) building a transport system; and (iv) storage of CO_2.[41] The cost ranges in Table 5 below in part reflect the likelihood that individual project costs will vary significantly.

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[39] The cost of CCS for non-power applications has not received the same attention as it has for the power sector. The IEA estimates that applying CCS technology to cement kilns would increase production costs by 40–90 per cent, with expected investment costs in 2050 of US$150–200/tonne of CO_2 abated.

[40] The three principal capture processes are oxy-fuel, post-combustion, and pre-combustion.

[41] The largest potential reservoirs for storing carbon are the deep oceans and geological reservoirs in the earth's upper crust. Storage is possible in diverse types of underground geological formations, including depleted oil and gas fields, depleted coal seams, and natural underground formations containing salty water, known as deep saline aquifers.

Table 5: Indicative carbon capture and storage system component costs

	Cost range (*a*)	**Cost range (*b*)**	**Remarks**
Capture from a coal- or gas-fired power plant	US$15–75/t$CO_2$ net captured.	€30/tCO_2 (US$40/t$CO_2$)	Net costs of captured CO_2 compared with the same plant without capture
Transportation	US$1–8/t$CO_2$.	€5/tCO_2 (US$6.7/t$CO_2$)	Transported per 250 km pipeline or shipping for mass flow rates of 5 (high end) to 40 (low end) Mt CO_2 in first year
Geological storage	US$0.5–8/t$CO_2$.	€10/tCO_2 (US$13.30/t$CO_2$)	Net injected excluding potential revenues from enhanced oil recovery or enhanced coal bed
Geological storage: monitoring and verification	US$0.1–0.3/t$CO_2$ injected.	—	This covers pre-injection, injection, and post-injection monitoring, and depends on the regulatory

Sources: (*a*) IPCC (2005); (*b*) early commercial projects in McKinsey (2008).

The bulk of the cost is attributable to (*a*) capturing the CO_2, viz. the additional capture-specific equipment, which raises required capital investment by about 50 per cent; and (*b*) an efficiency penalty (estimated at around 10 per cent), since energy absorbed in the capture process requires an increase in fuel consumption, as also an over-sizing of the plant to ensure the same electricity output.[42] Estimates of electricity costs from thermal power generation with CCS exhibit a fair dispersion, albeit around elevated levels compared to the *status quo*, as indicated in Tables 6 and 7 below.

[42] Although at this stage estimates are largely theoretical, there is little doubt that it is the capture part of the process that represents the bulk of the costs (70–90 per cent, according to one source), while transport and storage are relatively minor contributors to overall costs. Another source states that overall additional capital expenditure would contribute more than half (up to two-thirds) of the CO_2 capture cost at €14–19/tonne (US$18.50–25/tonne), while fixed and variable operational expenditure and fuel cost would be €5–7/tonne (US$6.50–9.50/tonne) and €2–6/tonne (US$2.60–8), respectively.

Table 6: Relative cost of electricity without and with CO_2 Capture[a]

	MIT	**GTC**	**AEP**	**GE**
PC no-capture, reference case	1.0	1.0	1.0	1.0
PC capture	1.60	1.69	1.84	1.58
IGCC no-capture	1.05	1.11	1.08	1.06
IGCC capture	1.35	1.39	1.52	1.33

Notes: PC: pulverized coal (super critical); IGCC: integrated gasification combined-cycle.
[a] Results reported in the MIT Coal Study (Deutch and Moniz, 2007), including from the Gasification Technology Council (GTC), General Electric (GE), and American Electric Power (AEP).

Table 7: Indicative costs—IPCC study (US$/kWh)

Power plant system	**Natural gas Combined-cycle**	**Pulverized coal**	**Integrated gasification combined-cycle**
Without capture (reference plant)	0.03–0.05	0.04–0.05	0.04–0.06
With capture and geological storage	0.04–0.08	0.06–0.10	0.05–0.09

Source: IPCC (2005).

DCs will find it very difficult (if not impossible) to deploy CCS without substantial financial support; they would simply not be able to afford electricity that is 66–100 per cent more expensive to produce compared to plants without CCS. Indeed, in the present context, the transfer of technology *per se* is not the critical issue; the principal challenge is who will pay for (eventually) decarbonizing thermal power generation in a country like India? (If the finance were available, the technology could be purchased when it becomes commercially available.)

(iv) Back-of-the-envelope calculation for India

During the 7 years, 2000/1–2006/7, India's total installed capacity increased at an average annual rate of 4.9 per cent (and electricity shortage intensified), with thermal capacity addition of 4 per cent/annum over the same period (GoI, 2008*a*).[43] If we (simplistically)

[43] Coal is the dominant fuel in India for electricity generation (about 70 per cent), with a share of over 40 per cent in the overall energy mix. Over time, the share of non-commercial energy (fuel wood, agricultural waste, and dung, essentially used by households for cooking) in total primary energy

extrapolate capacity addition at the same growth rate up to 2030, then during the 2020s (when CCS could be commercially available) total thermal capacity addition over the decade would be 77.4 GW. On the basis of the above scenario (and industry estimates of CCS equipment cost of US$1m/MW in 2020), India would have to undertake (on average) an annual expenditure in capture-specific capital of US$7.7 billion (at 2020 prices) over and above that for a thermal power plant. Indeed, this is an underestimate of total additional costs as it does not include the recurring costs of higher operating expenditure, extra fuel use for CCS-enabled power plants, and transport and storage of CO_2. It could be argued that installing 77.4 GW in the first decade that the technology is (possibly) commercially available, may be optimistic; if we were to trim it down to 50 GW, then the average annual capital investment would be obviously lower at US$5 billion/year.

Let us turn to estimating the financial implications (including compensation from an enhanced CDM outlined in the next sub-section) for India of abating CO_2. Coal-fired plants of India's largest thermal power utility, the NTPC, on average, emit 820g of carbon/kWh,[44] which compares favourably with plants elsewhere (see Table 8 below).

Table 8: Emissions intensity for thermal power generation (EU and US averages)

Fuel	**Tonnes of CO_2/MWhr**
EU:	
Coal	0.92
Oil	0.87
Gas	0.40
Lignite (old)	1.21
Lignite (new)	0.95
USA:	
Coal	0.98
Gas	0.42

Sources: Citigroup (2007) and EIA.

If we assume a plant load factor (PLF) of 75 per cent, 80 per cent of the capacity is coal-based, 20 per cent is natural-gas-based (where emissions/kWh is half of that from burning coal), and 90 per cent of emissions are captured (CO_2 prevented from being released into the atmosphere), then by 2030, 0.338 Gt of CO_2—about 15 per cent of total energy-related

requirement is expected to decline from 28 per cent at present as households transit to cooking gas and electricity (GoI, 2006).

[44] *Source*: NTPC analysis as reported in Bhaskar (2008).

BAU emissions in 2030—will be captured annually from CCS-enabled plants with an aggregate capacity of 77.4 GW.[45] At the mid-point of (real) expected CO_2 prices in 2030 of €30–48/tonne (US$40–63), 0.338 Gt of CO_2 abated, if compensated fully, could result in an inflow of US$17.4 billion in 2030; at the higher end of this range (which would cover most of the CCS-related costs described in Table 5) the magnitude will be of the order of US$21.3 billion.[46] At a different price of CO_2—say in the mid-point of the range, US$40–45—the inflow will be about US$14.4 billion.[47] If 50 GW of CCS-enabled thermal plants are installed, then the abatement in 2030 would be 0.218 Gt (a tenth of 2030 BAU emissions), with associated financial flows at various expected CO_2 prices of US$11.2 billion (mid-point of US$40–63); US$13.7 billion (US$63); and US$9.3 billion (mid-point of US$40–45).

In the absence of outright subsidies and grants, the economics of CCS rests on the (expected) price of CO_2, which can vary and, of course, there are no guarantees in a cap-and-trade system. However, it may be feasible to design hedging mechanisms/insurance—say, long-dated put options—to alleviate some (tail risk) aspects of price fluctuations in this regard. Among the many X-factors inherent in CCS, including safety (and 'live' data from yet-to-be-built industry-scale pilot projects), the potential in India for storing CO_2 underground (in natural rock formations, depleted oil and gas fields, and depleted coal seams) is yet to be comprehensively assessed, but this task need not take an inordinate amount of time. The National Geophysical Research Institute is probably best placed, in conjunction with the Directorate General of Hydrocarbons, to carry out Geocapacity surveys.

(v) Modalities of financing CCS: carbon trading or enhanced CDM

The continuing importance of coal in the global energy portfolio (especially for electricity generation) implies that development and dissemination of CCS technology is essential for emissions control of any significant magnitude.[48] India's involvement in this process is critical

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[45] The BAU emissions estimate of 2.24 Gt for 2030 is from EIA/IEO projections.

[46] CO_2 price estimates are from Deutsche Bank, UBS, Soc Gen, New Carbon Finance, and Point Carbon.

[47] This latter price—a trajectory that starts at US$25/tonne of CO_2 in 2015 and increases thereafter at a real rate of 4 per cent—is from Deutch and Moniz (2007).

[48] The foot-dragging over funding demonstration projects and the relative paucity of encouragement from policy-makers to its importance is baffling, given CCS's potentially central role in mitigation. Both difficult technical design and economic issues have to be solved, and a functioning regulatory framework for CCS needs to be established. The list of outstanding issues is long and includes access to land to test potential sites and monitor existing sites; establishing rules for third-party

for both India and the world. The main constraint is financial. The cleanest way to break the constraint from India's standpoint would be for India to be a full member of the carbon-trading mechanism, but with a generous allocation of permits that would enable it to sell them and buy the relevant technology.[49] (The same argument would apply to any DC that was willing to take on carbon targets.) Note also that countries with a cap under Kyoto have the option of 'Joint Implementation', whereby member states can acquire carbon credits by investing in emissions-reducing projects in other member states' markets. If India joined a mitigation treaty, such a scheme may have the potential to attract CCS investments into the country.

But the best should not become the enemy of the good. If India cannot get the right terms to join a mitigation treaty, it will have to obtain financing for CCS via the existing Clean Development Mechanism (CDM). CDM is at present the only market instrument in the Kyoto Protocol where DCs participate (China and India are, by far, the largest beneficiaries of the CDM). The CDM has been a modest success in terms of financing mitigation in DCs whereby Certified Emission Reductions (CERs), issued to developing country sponsors who can show that their projects will emit less than the stipulated baseline, can be bought by EU emitters so that the latter can emit beyond their allocation. In the most optimistic scenario, if the current 400-project per year capacity of the CDM is fully successful in terms of both registration and issuance of expected CERs, the resultant annual financial flows to developing countries will be in the region of US$6 billion at current carbon prices. Issues regarding the veracity of additionality of reduction in emissions, and the high transaction cost of the CDM have been discussed elsewhere (Stern, 2008*b*; Wagner *et al.*, 2008).

If CCS is ready for large-scale deployment by 2020, a CCS-specific facility for using the technology extensively in DCs is an option. A relatively uncomplicated course would be to expand the scope of the CDM, call it C-CDM, to incorporate sequestration of CO_2 as an offset that can be traded into a carbon-trading system. (Of course, the storage of CO_2 will need to be demonstrated/guaranteed for a minimum period of time to ensure that credits are justified on a scientific basis.) There is no obvious reason that CO_2 sequestered from sources such as cement plants, steel plants, etc. cannot also be incorporated in the C-CDM

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access to infrastructure (transport, injection, or storage); competing land uses (between extractor and sequesterer); long-term liability over leakage; and CO_2 ownership. Governments may, at the least, be required to indemnify early developers from CO_2 leakage to kick start meaningful industry-scale (pilot) projects. For a planned project in Florida even permitting requirements have not been forthcoming, although the utility is ready to deploy CCS experimentally.

[49]A scheme in this spirit has been proposed by Wagner *et al*. (2008).

in due course. Others have gone even further. Teng *et al.* (2008) argue that to further incentivize carbon-efficient electricity generation, there is a case for inclusion in an expanded CDM of emissions 'saved' by installing natural-gas combined-cycle (NGCC) power capacity *without* CCS, since CO_2 emissions from gas-based plants are around half of those from coal (which is the alternative fuel).

Broadening the CDM to recognize CCS would enhance financial flows to DCs, and since thermal power plants entail large (and more or less similar) investments, the overhead cost related to CDM may turn out to be less onerous for these projects (a relatively easy cookie-cutter approach may be possible). In other words, reduction of transaction costs per unit of emissions—through greater learning-by-doing and learning-by-looking—linked with effective compliance, monitoring, verification, and trading is feasible with a wholesale or programmatic approach.[50] Second, additionality of abatement through a C-CDM will be genuine, whereas there are doubts over whether some segments of the present portfolio of projects that are eligible for credits actually constitute additionality in emissions reduction. Third, a credibly instituted C-CDM, including demonstration by ACs to pay for it, will imbue confidence about the extensive future demand for CCS—a couple of externally funded pilot projects in India and China will confirm intent—and hence catalyse R&D, investment, and entrepreneurship into the sector. On this count, economies of scale could be significant; for example, it is estimated that the total CCS cost (for new power installations) of abatement could be lower by US$6.50/tonne of CO_2 if there was a global roll-out of 500–50 projects by 2030 compared to a relatively limited roll-out in Europe of 80–120 projects.

VII. Concluding remarks: India's negotiating position

DCs feel that their economic progress will be curtailed by the extant stock of GHGs, most of which have been emitted by the ACs, and therefore that the costs of climate-change mitigation should squarely be borne by the latter. Given India's development imperatives and low *per capita* carbon footprint, it is not surprising that India subscribes to this view. The argument is even more compelling when we appreciate some specific Indian problems, for example hugely inadequate access to electricity for basic lighting, and dependence on non-

[50] Power generation with CCS is 'big ticket' (500 MW and beyond), hence transaction costs are bearable (normalized by size of project); it is an archetypical concentrated, rather than dispersed, emission source. Currently, from validation to registration, the CDM regulatory process on average takes about 300 days, and the associated transaction costs can easily reach half a million dollars.

traditional fuels for cooking. It is obvious that coal will continue to be the dominant fuel for power generation in India (and elsewhere) for reasons already outlined. CCS technology for decarbonization of thermal power generation is critical for meaningful emissions reduction by 2050. But CCS is expensive and will almost double the cost of electricity from coal-fired stations, which consumers in poor countries will simply not be able to pay for. Compensation to India for deploying this technology would be possible, *either* through the allocation of adequate emission allowances that can then be sold to defray the cost of CCS (among other costly abatement measures) and concomitantly reduce the cost to consumers of decarbonized power, *or* by widening the scope of the present project-oriented CDM. The former alternative is preferred because we favour India becoming a full member of a mitigation treaty, if it can secure the right terms.

India has so far been opposed to joining an international climate mitigation treaty. In our view, this negative stance should be abandoned. If India can get the appropriate terms, including an appropriate quantity of ‘hot air’ or ‘headroom’ in the allocation of permits, its interests would be best served by participation. We offer the following reasons for our view.

First, climate-change mitigation requires both a high price of carbon across the world as well as investment in clean-energy R&D. The former is a necessary condition for success in the latter and requires a global agreement with a tight overall cap. It is in India’s interest to help achieve a comprehensive agreement, since India is particularly vulnerable to climate-change damage.

Second, neither the USA nor China would join a treaty without the other, and India is also a key player. India’s willingness to join may play a catalytic role in motivating participation by the USA and China.

Third, India should join a treaty only if the terms are right, and this is, of course, a matter of negotiation. If India joins ahead of other DCs, it could secure a first-mover advantage in terms of obtaining a permit allocation with adequate ‘headroom’ to compensate it for the costs of mitigation. (India would doubtless push for permit allocations based on *per capita* emissions or *per capita* income. While this may serve as an initial bargaining move, its chances of success are negligible. A reasonable fall-back position would be to insist on an allocation with enough 'headroom' to compensate India fully for the welfare cost of undertaking its share of global mitigation.[51])

Fourth, India may be able to use its offer to join a treaty to get other things it wants—climate-related (for instance, credible long-term adaptation finance), and/or climate-unrelated (a seat on the UN Security Council? increased voting power in the IMF?). Note that when Russia joined the Kyoto agreement, it extracted the price of Western assistance in joining the WTO.

Fifth, unless the CDM is modified (given the problems associated with proving 'additionality' of emissions reductions), opposition to it may increase and the conditions surrounding it could become more circumscribed. One worry about expanded participation in the CDM which is frequently aired is that credits for India's 'low hanging fruit' projects would then be sold cheaply to ACs; the conclusion is drawn that such projects should be held back in case India eventually joins a mitigation treaty. However, the right inference is that India should join such a treaty soon. Permits in the European carbon-trading scheme currently trade at higher prices than CERs for a variety of reasons. If India were to join, and depending on the baselines accepted, it may get high prices for its 'low hanging fruit' projects. Why then does India fear joining a treaty? It is felt that it could be disadvantageous to India to be bound by emissions targets. This would not be the case if India could secure a permit allocation with adequate 'headroom', including built-in flexibility for upward revision if GDP growth turns out to be faster than expected.[52] (A 'zero welfare cost' criterion for permit allocation would of course cover this point.)

Sixth, if a treaty succeeds and India joins late, it faces the risk of being stuck with too many low-value, high-carbon assets. If India joins early and the treaty unravels, not much is lost since, assuming that the terms are right, India will have been compensated in the interim by the sale of permits.

Seventh, a mitigation treaty cannot succeed without some enforcement mechanism. The obvious one is trade restrictions against non-participants. This is a danger that India would avoid by joining a treaty.

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[51] This underscores the importance of research to establish the magnitude of the welfare cost.

[52] Of course, it may well make sense for India to press for and make use of an expanded CDM (see section VI) *either* as a stepping-stone on the way to joining a mitigation treaty *or* as a fall-back position if the right terms cannot be obtained for treaty participation.

Lastly, India has to be wary of the changing dynamics of international *realpolitik*. While important developing countries such as China have hitherto taken a position in the climate-stabilization arena that is practically identical to India's, it cannot be ruled out that this may alter in the future. China's economy is substantially larger than India's, and China increasingly sees itself as a super power in-waiting; it could choose to enhance its standing—as a responsible aspiring power—by joining a treaty (to earn kudos, and/or secure some tangible *quid pro quo*[53]). If something akin to this comes to pass, it is not inconceivable that India could be isolated, and eventually be forced to accept an inferior 'done' deal.[54]

In sum, India should regard the issue of climate-change mitigation as a diplomatic challenge of getting the right terms, not as a bugbear to be feared and shunned. It should declare itself willing to negotiate to join a mitigation treaty, say in 2020, *provided* (i) the ACs demonstrate their good intent by making significant actual reductions in emissions by 2020; and (ii) the ACs are ready to admit India on equitable terms. The second condition involves agreeing on an allocation formula for permits which would compensate India for its mitigation costs for several decades.

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[53] The latter could, for example, be a promise to keep India away from the diplomatic 'top table'.

[54] There is some 'chatter' about the USA and China working together on 'climate'.

Data appendix

Table A1(*a*): Energy-related CO_2 emissions (in gigatonnes), and allied data

Region/country	1990	2005	2010	2020	2030	Average annual % change in CO_2	PPP GDP in 2030 (in billion 2000	Average annual % change in GDP	Metric tonnes/million 2000 US$ PPP GDP (2030)	Average annual % change in
World	21.2	28.1	31.1	37.0	42.3	1.7	150,182	4.0	282	–2.2
USA	4.99	5.98	6.01	6.38	6.85	0.5	20,219	2.5	339	–1.7
OECD Europe	4.10	4.38	4.51	4.76	4.83	0.4	20,076	2.3	241	–1.8
OECD Asia	1.54	2.17	2.21	2.32	2.40	0.4	7,694	1.8		
Japan	1.01	1.23	1.20	1.20	1.17	–0.2	4,467	1.1	262	–1.2
Total OECD	11.40	13.57	13.83	14.74	15.54	0.5	52,542	2.3	296	–1.8
Non-OECD	9.83	14.49	17.27	22.30	26.79	2.5	97,640	5.2	274	–2.6
China	2.24	5.32	6.90	9.48	12.01	3.3	35,973	6.4	334	–2.9
Russia	2.38	1.70	1.79	1.98	2.12	0.9	5,404	4.0	392	–3.0
India	0.57	1.16	1.35	1.82	2.24	2.6	16,524	5.8	135	–3.0
Brazil	0.22	0.36	0.45	0.54	0.63	2.3	3,896	3.6	162	–1.2
Middle East	0.70	1.40	1.62	1.99	2.25	1.9	4,174	4.0	539	–2.6

Source: EIA (2008*b*).
Note: PPP is purchasing power parity.

Table A1(*b*): *Per capita* energy-related CO_2 emissions (in tonnes)

Region/country	1990	2005	2010	2020	2030	Average annual % change (1990–2005)	Average annual % change (2005–30)
World	4.0	4.3	4.5	4.8	5.1	0.5	0.7
USA	19.6	20.1	19.3	18.9	18.7	0.2	–0.3
OECD Europe	8.3	8.2	8.3	8.5	8.5	–0.1	0.2
Japan	8.2	9.6	9.4	9.6	9.9	1.1	0.1
Total OECD	10.9	11.6	11.5	11.7	12.0	0.4	0.1
Every one else	2.3	2.7	3.0	3.5	3.8	1.1	1.4
China	2.0	4.1	5.1	6.7	8.2	5.0	2.9
Russia	16.0	11.8	12.7	15.0	17.1	–2.0	1.5
India	0.7	1.0	1.1	1.3	1.5	3.0	1.5
Brazil	1.4	1.9	2.3	2.5	2.7	1.9	1.4
Middle East	5.1	7.3	7.6	7.8	7.7	2.4	0.2

Source: Same as A1a.

Table A2(*a*): Energy-related CO_2 emissions in the reference scenario (in gigatonnes)

Region/country	1980	1990	2000	2006	2020	2030
OECD	10.65	11.04	12.43	12.79	13.31	13.17
North America	5.30	5.57	6.54	6.62	6.95	7.06

USA	4.66	4.85	5.66	5.67	5.77	5.80
Europe	4.12	3.89	3.90	4.06	4.16	3.99
Pacific	1.23	1.58	1.99	2.11	2.21	2.11
Japan	0.88	1.07	1.19	1.21	1.15	1.06
Non-OECD	6.85	9.29	10.17	14.12	21.89	26.02
E.Europe/Eurasia	3.41	4.03	2.45	2.65	3.18	3.34
Russia	n.a.	2.18	1.50	1.57	1.92	2.00
Asia	2.14	3.52	5.20	8.36	14.17	17.30
China	1.42	2.24	3.08	5.65	10.00	11.71
India	0.29	0.59	0.98	1.25	2.19	3.29
Middle East	0.34	0.59	0.97	1.29	2.09	2.61
Africa	0.41	0.55	0.69	0.85	1.08	1.17
Latin America	0.55	0.60	0.86	0.97	1.38	1.60
Brazil	0.18	0.19	0.30	0.33	0.50	0.58
World[a]	18.05	20.95	23.41	27.89	36.40	40.55
EU	n.a.	4.04	3.08	3.94	3.95	3.76

Notes: [a] Includes emissions from international marine bunkers and international aviation; n.a.: not available. *Source*: *World Energy Outlook* (IEA, 2008*b*).

Table A2(*b*): *Per capita* energy-related CO_2 emissions in the reference scenario (in tonnes)

Region/country	1980	1990	2000	2006	2020	2030
OECD	11.0	10.5	11.0	10.8	10.5	10.1
North America	16.5	15.3	15.7	15.0	13.9	13.2
USA	20.2	19.1	19.7	18.6	16.8	15.8
Europe	8.7	7.8	7.5	7.5	7.4	7.0
Pacific	7.1	8.4	10.1	10.5	10.9	10.7
Japan	7.5	8.7	9.4	9.5	9.3	9.0
Non-OECD	2.0	2.2	2.1	2.6	3.5	3.8
E.Europe/Eurasia	10.6	11.6	7.1	7.8	9.6	10.4
Russia	n.a	14.7	10.3	11.0	14.6	16.3
Asia	0.9	1.3	1.6	2.4	3.6	4.1
China	1.4	2.0	2.4	4.3	7.0	8.0
India	0.4	0.7	1.0	1.1	1.6	2.3
Middle East	3.7	4.5	5.9	6.8	8.5	9.3
Africa	0.9	0.9	0.9	0.9	0.9	0.8
Latin America	1.9	1.7	2.1	2.1	2.6	2.8
Brazil	1.5	1.3	1.7	1.8	2.3	2.5
World*	4.1	4.0	3.9	4.3	4.8	4.9
EU	n.a	8.6	7.9	8.0	7.9	7.5

Source: See Table A2(*a*).

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