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Opportunities to change development pathways toward lower greenhouse gas emissions through energy efficiency

Author
Sathaye, Jayant

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J. Sathaye* & E. Masanet Lawrence Berkeley National Laboratory, Berkeley, CA, USA
*e-mail: jasathaye@lbl.gov

F. Lecocq French National Institute for Agricultural Research, Nancy, France

F. Lecocq AgroParisTech, Engref UMR 356 Economie Forestière, F54000 Nancy, France

A. Najam Boston University, Boston, MA, USA

R. Schaeffer Federal University of Rio de Janeiro, Rio de Janeiro, Rio de Janeiro, Brazil

R. Swart Alterra/Wageningen University and Research Centre, Wageningen, The Netherlands

H. Winkler University of Cape Town, Cape Town, South Africa

Abstract: There is a multiplicity of development pathways in which low energy sector emissions are not necessarily associated with low economic growth. However, changes in development pathways can rarely be imposed from the top. On this basis, examples of energy efficiency opportunities to change development pathways toward lower emissions are presented in this paper. We review opportunities at the sectoral and macro level. The potential for action on nonclimate policies that influence energy use and emissions are presented. Examples are drawn from policies already adopted and implemented in the energy sector. The paper discusses relationships between energy efficiency policies and their synergies and tradeoffs with sustainable development and greenhouse gas emissions. It points to ways that energy efficiency could be mainstreamed into development choices.

Keywords: Sustainable development . Energy efficiency . GHG emissions . Synergies and tradeoffs . Mainstreaming

Introduction[1]

The concept of sustainable development has its roots in the idea of a sustainable society (Brown 1981) and in the management of renewable and nonrenewable resources. The World Commission on Environment and Development adopted the concept and launched sustainability into political, public, and academic discourses. The concept was defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED 1987; Bojo et al. 1992).

While there are many definitions of sustainable development, the international sustainability discourse is helping to establish some commonly held principles of sustainable development. These include, for instance, the welfare of future generations, the maintenance of essential biophysical life support systems, ecosystem well-being, more universal participation in development processes and decision making, and the achievement of an acceptable standard of human wellbeing (WCED 1987; Meadowcroft 1997; Swart et al. 2003; Millennium Ecosystems Assessment 2005).

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[1] This paper is based on Chapter 12 of the Intergovernmental Panel on Climate Change (IPCC; Sathaye et al. 2007)on Sustainable Development and Mitigation. It represents a condensed version of the chapter with a focus on energy efficiency. In addition, new material has been added in “Historical evidence of changes in carbon intensity”, “Historical evidence of changes in energy intensity”, “Mainstreaming climate change into development choices”, and “Role of governance” sections, Box 1, and Appendix.

Much of the IPCC mitigation assessment and its underlying literature focuses on climate change mitigation that considers climate change programs and policies in their own right ("climate first"). Recent literature has focused more broadly on treating climate change mitigation as an integral element of development policies ("development first"). Energy efficiency is a key component for ensuring effective use of resources that leads to lower global greenhouse gas (GHG) emissions. More efficient use of energy and other resources also has the benefit of reducing emissions of other pollutants, while requiring lesser or smaller infrastructure to support the same level of development. Cobenefits of energy efficiency are often synergistic and can thus lead to substantial improvement in broader development objectives of a country. Energy efficiency options are typically less costly and combined with aforementioned environmental benefits they contribute to "development first" options.

Energy efficiency options are also important elements of the process for "making development more sustainable". Making development more sustainable recognizes that there are many ways in which societies balance the economic, social, and environmental, including climate change, dimensions of sustainable development. It also admits the possibility of conflict and tradeoffs between measures that advance one aspect of sustainable development while harming another (Munasinghe and Swart 2000). For a development path to be sustainable over a long period, however, wealth, resources, and opportunity must be shared so that all citizens have access to minimum standards of security, human rights, and social benefits, such as food, health, education, shelter, and opportunity for self-development (Reed 1996).

This paper explores ways to make development more sustainable. "Development paths and emissions scenarios" section explores the role of development paths and their relationship to carbon and energy intensity and the opportunities to change these paths at the sectoral level. "Mainstreaming climate change into development choices" section discusses ways to mainstream climate change mitigation into development choices. Both synergies and tradeoffs between mitigation options and sustainable development and adaptation activities are explored. Finally, "Role of governance" section focuses on the role that state, market, and civil society need to play in mainstreaming climate change mitigation into development choices.

Development paths and emissions scenarios

This section discusses the link between development paths[2] and GHG emissions. In the first two sections below, we address the concern that emissions and energy use might be directly linked to economic growth. In the next section, a quick review of the opportunities to change sectoral development paths is provided with examples of the accomplishments of several countries.

Historical evidence of changes in carbon intensity

Economic activity is a key driver of CO_2 emissions. How economic growth translates into new emissions, however, is ambiguous. As the economy expands, demand for and supply of energy and of energy-intensive goods also increases, pushing CO_2 emissions upward. On the other hand, economic growth may drive technological change, increase efficiency, and foster the development of institutions and preferences more conducive to environmental protection and emissions mitigation. Also, economic growth may be associated with specialization in sectors with low (or high) emissions per unit of output, such as services, manufacturing, or heavy industries, thus resulting in a faster (or slower) delinking between domestic emissions and gross domestic product (GDP).

[2] Development paths are defined here as a complex array of technological, economic, social, institutional, cultural, and biophysical characteristics that determines the interactions between human and natural systems, including consumption and production patterns in all countries, over time at a particular scale. Development paths will be different in scope and timing in different countries and can be different for different regions within countries with large differences in internal regional characteristics.

There is a growing empirical literature on the relationship between economic growth and CO_2 emissions. Studies using GDP and emissions data over multiple countries and multiple time periods consistently find that GDP per capita and emissions per capita move in the same direction among most or all of the sample (e.g., Schmalensee et al. 1998; Ravallion et al. 2000; Heil and Selden 2001). A 1% increase in GDP per capita was found to lead to an increase in CO_2 emissions per capita between 0.5% to 1.5%. All studies also find evidence that this coefficient is not constant but varies as per capita income rises. Until recently, these studies consistently found a relationship between per capita GDP and per capita CO_2 emissions such that, beyond a certain level of GDP per capita (usually, but not always, higher than the highest per capita GDP in the sample considered), per capita CO_2 emissions would start decreasing as income increase. However, Harbaugh et al. (2002) and Millimet et al. (2003) cast doubt on this last finding and claim that the econometric relationship between GDP and emissions data is less robust than previously thought.

Studies using time series at the country level typically find less robust relationships between GDP per capita and CO_2 emissions per capita. For example, Moomaw and Unruh (1997) show that international oil price shocks and not per capita GDP growth explain most of the variations in per capita emissions in Organization for Economic Cooperation and Development (OECD) countries. Similarly, Coondoo and Dinda (2002) find a strong correlation between emissions and income in developed countries and in Latin America, but a weaker correlation in Africa and Asia. This is consistent with recent findings from the (broader) literature on the relationships between GDP per capita and pollution. For example, Dasgupta et al. (2006) show that the relationship between GDP per capita and pollution mostly disappears when other explanatory variables, notably governance, are introduced. Neither taking trade into account as a new explanatory variable nor correcting emissions for trade effects, however, significantly increases the robustness of the correlation between observed levels of GDP per capita and observed levels of emissions.

To sum up, the econometric literature on the relationship between GDP per capita and CO 2 emissions per capita does not support an optimistic view that “the problem will take care of itself” because richer people will automatically emit less. On the other hand, the monotonically increasing relation between economic activity and CO_2 emissions that emerges from the data does not appear to be econometrically very robust, especially at country level and at higher GDP per capita level. In other words, the pessimistic interpretation that growth and CO_2 emissions would be irrevocably linked is not supported by the data either. There is apparently some degree of flexibility between economic growth and CO_2 emissions.

For example, CO_2 emissions from fossil fuel combustion in China remained essentially constant from 1997 to 2001 despite a +30% growth of GDP due to inter alia a combination of closing of small-scale, inefficient power plants, shift in industry ownership away from the public sector and introduction of energy efficiency and environmental regulation (Streets et al. 2001; Wu et al. 2005).

Another example of how very different development paths can unfold in relatively similar countries is given by Hourcade and Kostopoulou (1994) who analyze how France, Italy, Germany, and Japan—countries with similar levels of GDP per capita in 1973—responded to the first oil shock. They show that France moved aggressively to develop domestic supply of nuclear energy and a new building code that Japan made an aggressive shift of its industry toward less energy-intensive activities and simultaneously used its exchange-rate policies to alleviate the burden of oil purchases and that Germany built up industrial exports to compensate the trade balance deficit in the energy sector. Much of the variations of CO_2 emissions per unit of GDP from 1971 to 1990 can be attributed to these choices. Yet, CO_2 emissions per unit of GDP diminished by half in France, by a third in Japan, and “only” by a quarter in Germany. At the same time, the macroeconomic performances of these countries have been relatively comparable from 1973 to 1990 (Fig. 1 right), suggesting that widely different environmental outcome can be obtained at similar welfare costs in the long run.

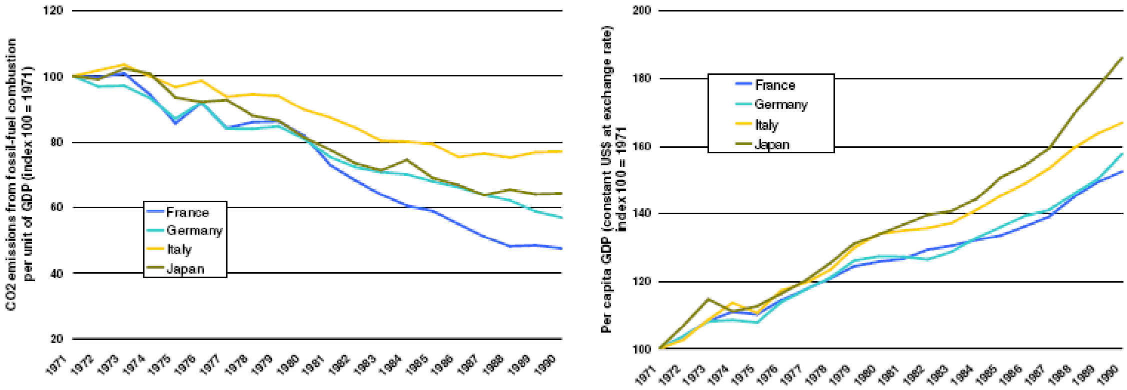


Fig. 1 Left: Evolution of CO_2 emissions from fossil fuel combustion in France, Germany, Italy, and Japan between 1971 and 1990; right: Evolution of GDP per capita in France, Germany, Italy, and Japan between 1971 and 1990. Data source: IEA (2004a)

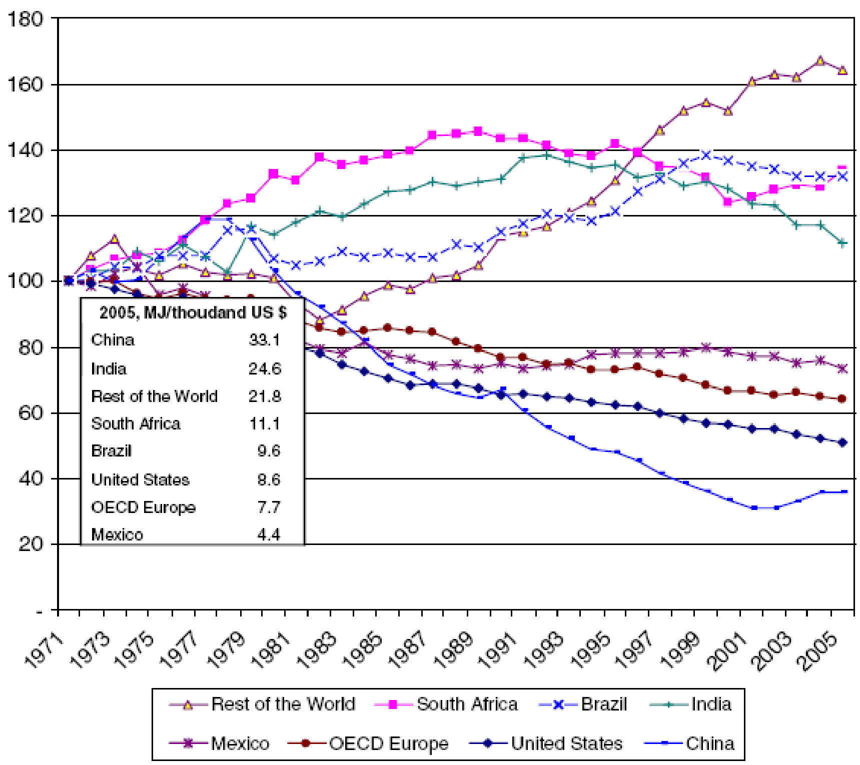
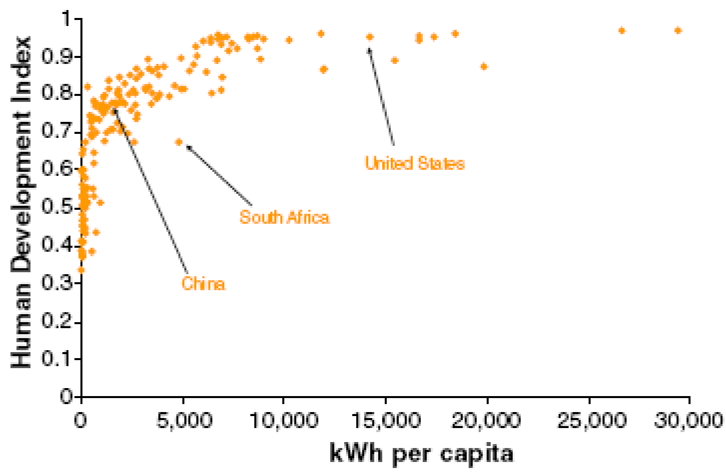


Fig. 2 Primary energy supply per unit of GDP (excluding biomass; MJ/US $2,000 market exchange rate; indexed to 1971, using IEA data)

Historical evidence of changes in energy intensity

Energy intensity is defined as energy use per unit of GDP and is an aggregate measure of the energy productivity of an economy. Changes in energy efficiency are one factor that explain changes in energy intensity. Energy intensities vary by country and are influenced by other factors such as natural resource endowments, economic structure, and climate regimes. Figure 2 shows the changes in energy intensity since 1970 for several developed and developing countries. Oil price shocks in the 1970s were a key driver for improved vehicle fuel economy, shift away from oil-fired power plants, and the tightening or initialization of efficiency standards in OECD countries. These resulted in a sharp decline in energy intensity that has continued since then. Over the period 1973–1998, the IEA (2004a, b) estimates that the decline in energy intensities— driven both by policies and by autonomous technical improvements—have resulted in energy savings corresponding to almost 50% of 1998 IEA-11 energy consumption levels. In other words, absent these savings, energy use (and CO_2 emissions) in 1998 would have been almost 50% higher than observed. The Chinese economy promoted and implemented strict energy efficiency regulatory measures that resulted in an energy/GDP elasticity of 0.5 until 2002. Energy intensity of the Indian economy, on the other hand, only started to decline since the early 1990s after the economic liberalization in 1991 and has accelerated since 1997. A rapid capital stock turnover brought about by faster economic growth and the advent of the information technology sector both contributed to this decline.

Figure 3 below highlights the relationship between changes in electricity intensity and sustainable development attributes and illustrates that it is not a rigid connection and can be decoupled. A high human development index (HDI; >0.85) may be achieved at a level of annual electricity consumption that stretches from about 7,000 to 30,000 kWh/capita/year[3]. On the other hand, a wide range of human development is seen at low levels of electricity consumption—but not the highest. In the case of South Africa and other similar countries, high electricity consumption does not necessarily result in a high HDI. The structural factors driving energy intensity—a focus on the minerals–energy complex and low levels of efficiency— and lower life expectancy due to HIV/AIDS had outweighed any shifts toward less energy-intensive economic activities over time in that country.



Source: UNDP (2007)

Fig. 3 Human development compared to electricity consumption

Opportunities to change development paths at the sectoral level

In "Historical evidence of changes in carbon intensity" and "Historical evidence of changes in energy intensity" sections, we have argued that the link between GHG emissions, energy use, and economic activity was not rigid at the macro level: There are examples of countries with comparable economic performances and very different GHG emissions. In the present section, we provide examples of decoupling between GHG emissions and increased and/or improved activity—i.e., changes in

[3] The HDI is a composite index including literacy, life expectancy, and GDP per capita. All electricity consumption is attributed to individuals.

development paths—at the sectoral level. To be as relevant to decision making as possible, we group these examples by policies that are susceptible to lead to a shift in development path. In line with the general topic of this article, we draw examples mostly from the energy sector—but use transportation to show how the same logic applies to other sectors as well. Finally, though some policies, such as energy efficiency or energy subsidy removal, lead mostly to reduced emissions, we also present examples where the link is more ambiguous.

Policies that increase energy efficiency—both on the demand and on the supply side—aim at reducing demand for energy without affecting, or while increasing, output at very low costs. However, some of the direct gains might be offset by increased demand due to lower energy costs per unit of output (rebound effect), either directly or via macroeconomic adjustments. Empirical estimates vary, but suggest that the rebound effect is in general small to moderate (e.g., Greening et al. 2000; Small and Van Dender 2007). The impact on CO_2 emissions, in turn, tends to be positive, but depends heavily on the carbon content of the energy supply. For example, Gillingham et al. (2006) estimate that the annual energy savings generated by all current demand-side management programs in the USA represent about 6% of the country's nontransportation energy consumption and lead to reductions in CO_2 emissions equivalent to (at most) 3.5% of the country's total. Appendix shows additional examples of the energy savings achieved in Brazil and South Africa through the use of energy efficiency policies.

In the energy sector, implications of improved access to commercial fuels on GHG emissions are ambiguous. Emissions from fossil fuels increase, albeit by a small margin. But unsustainable use of fuel wood and related deforestation decreases (Davidson and Sokona 2002). Similarly, electrification increases emissions as a result of easier access and induced economic benefits. But emissions per unit of energy consumed might decrease if the carbon content of the electricity that is newly provided is lower than the carbon content of the fuel it displaces (de Gouvello and Maigne 2000).

The impact of energy subsidies removal on CO_2 emissions is likely to be positive in most cases, as higher prices trigger lower demand for energy and induce energy conservation. Removal of energy subsidies has been identified as instrumental in reducing GHG emissions relative to business as usual in China and India over the past 20 years (Chandler et al. 2002). But subsidies removal may result in increased emissions if poor consumers are forced off-grid and back to highly carbon intensive fuels, such as nonsustainable charcoal or diesel generators.

The impact of *energy security* policies on emissions is ambiguous, depending in particular on the fuel sources being favored. For example, in response to the first oil shock, Brazil launched in 1975 the National Alcohol Fuel Program to increase the production of sugarcane ethanol as a substitute for oil, at a time when Brazil was importing about 80% of its oil supply. This program resulted in an estimated 1.5 Mt CO_2/year emission savings (Szklo et al. 2005a). But Brazil also provides an example where emissions increased as a result of energy security-driven policies. During the 1990s, Brazil faced lack of investment in the power system and a growing supply–demand imbalance, culminating in electricity shortage and rationing in 2001. This forced the country to install and run emergency fossil fuel plants, leading to a substantial increase in GHG emissions (Geller et al. 2004).

Emissions from the transportation sector result from the combination of the amount of travel that goods and people make and of the set of technologies with which those trips are undertaken. A wide array of policies affect both demand for transportation and technologies. For example, Nivola (1999) argues that the differences in urban forms between American and European cities—sprawled vs. compact—cannot be explained only by differences in demography, geography, technology, or income and stem from major differences in public policies in the USA relative to Europe: an acute bias toward public financing of roads against other modes of transportation, dedicated pools of resources for highway construction (while funds are drawn from general revenues in Europe), lower taxes on gasoline, housing policies more geared toward supporting new homes, a tax system more in favor of homeowners, lower support from the federal Government to local governments, and the quasi-absence of regulations favoring small in-city outlets against shopping malls. This difference in urban forms, in turn, generates widely different demands for transport services, for energy consumption, and for CO_2 emissions.

Although the examples discussed above are very diverse, some general patterns emerge from the literature. First, any country is likely to have opportunities to adopt "win-win-win" policies, i.e., policies that free up resources and bolster growth, meet other sustainable development goals, and also, incidentally, reduce GHG emissions relative to baseline (for example, improving efficiency in sectors using highly energy inefficient equipment). Conversely, the closer one gets to the production frontier, the more tradeoffs are likely to appear between reducing emissions and meeting other goals (Hourcade et al. 1996). Second, because some of the key dynamics for GHG emissions, such as technological development or land-use patterns, present a lot of inertia and thus need sustained effort to be oriented, what matters is not only that a "good" choice is made at a certain point in time but also that the initial policy persists for a long time—sometimes several decades—to truly have effects. For example, Nivola (1999) points out that sustained policies over time are critical to change the dynamics of urban forms. This raises deep institutional questions about the possibility of governments to make credible long-term commitments (Stiglitz 1998). Finally, it is often not one policy decision, but an array of decisions that are necessary to influence emissions. This raises, in turn, important issues of coordination between policies in several sectors and at various scales.

Mainstreaming climate change into development choices

The sections above have highlighted that development policies in various sectors can have strong impacts on GHG emissions. The operational question is how to harness that potential. In other words, how can climate change mitigation considerations be mainstreamed into development policies?

Mainstreaming means that development policies, programs, and/or individual actions that otherwise would not have taken climate change mitigation into consideration explicitly include these when making development choices. This makes development more sustainable. The extent to which mainstreaming leads to a sustainable development path will depend on the technological, social, and other constraints that limit the current and future development path trajectory.

The ease or difficulty with which mainstreaming is accomplished will depend on both the mitigation technology or practice and the underlying development path. No-regrets energy efficiency options, for instance, are likely to be easier to implement (and be labeled as climate change mitigation actions) than others that have higher direct cost, require coordination among stakeholders, and/or require a tradeoff against other environmental, social, and economic benefits. Weighing other development benefits against climate benefits will be a key basis for choosing development sectors for mainstreaming climate change considerations. In some cases, it may even be rational to disregard climate change considerations because of an action's other development benefits (Smith 2002).

Development policies, such as electricity privatization, can increase emissions if they result in construction of natural gas power plants in place of hydroelectric power for instance, but they can reduce emissions if energy efficiency (demand-side management) programs avoid coal or other fossil-fuelled power plants from being built. Judicious and informed choices will be needed when pursuing development policies in order to ensure that GHG emissions are reduced and not increased (see "Appendix").

There are many different types of nonclimate development policies in which climate mitigation activities can be mainstreamed. Examples of these include (1) rationalized energy and water pricing and ban on import of inefficient equipment, (2) forest conservation and sustainable forest management practices that can contribute to conservation of biodiversity, watershed protection, rural employment generation, increased incomes to forest dwellers and carbon sink enhancement, (3) increased market penetration of cost-effective energy efficiency technologies in electricity generation, transmission, distribution, and end use which will also reduce local pollution, (4) reducing oil imports as a strategy to improve energy security while minimizing the use of coal as a substitute and increasing use of less-carbon-intensive energy sources and reducing energy intensity of the economy (IEA (International Energy Agency) 2004b), (5) provision of incentives by multilateral development banks in their own lending to directly and indirectly influence the emissions of borrowing countries, and (6) insurance premiums differentiated to reflect vehicle fuel economy; liability insurance exclusions for large emitters; improved terms to recognize the lower risks associated with green buildings; or new insurance products to help manage technical, regulatory, and financial risks associated with emissions trading (Mills 2003).

Mainstreaming mitigation options will depend on the mitigative capacity of each country. Winkler et al. (2007) have suggested that mitigative capacity be defined as “a country’s ability to reduce anthropogenic greenhouse gases or enhance natural sinks.” Higher levels of development tend to increase mitigative (and adaptive) capacity (Sathaye et al. 2007). To show this, capacity can be assessed on the basis of objective factors such as costs, institutions, and technology, together with more subjective factors such as political willingness (Winkler et al. 2007). Mitigative capacity of different countries is shaped by two economic factors, namely, average abatement cost (or mitigation potential; high cost means low potential) and ability to pay, as approximated by GDP per capita. A significant portion of the mitigation potential would be realized through energy efficiency.

Implications of mitigation choices for sustainable development goals

Mitigation options often have positive effects on aspects of sustainability, but may not always be sustainable with respect to all three dimensions of sustainable development (SD)—economic, environmental, and social. For example, removing subsidies for coal increases its price and creates unemployment of coal mine workers, independently of the actual mitigation (IPCC 2001a, b). In some cases, the positive effects on sustainability are more indirect, because they are the results of side effects of reducing GHG emissions. Therefore, it is not always possible to assess the net outcome of the various effects.

The sustainable development benefits of mitigation options vary over sectors and regions. Generally, mitigation options that improve productivity of resource use, whether it is energy, water, or land, yield positive benefits across all three dimensions of sustainable development. In the agricultural sector for instance, improved management practices for rice cultivation and grazing land and use of bioenergy and efficient cook stoves enhance productivity and reduce the burden on women of finding and gathering fuel wood often in harsh environments. Other categories of mitigation options have a more uncertain impact and depend on the wider socioeconomic context within which the option is being implemented. Some energy efficiency mitigation activities with GHG benefits may be of limited duration without the persistent replacement and long-term use of the efficient device.

Evaluation of mitigation policies typically focuses on cost estimates that may be reported for each sector at both the global and country-specific levels. Yet, mitigation costs are just one part of the broader economic impacts of SD. Other impacts include growth and distribution of income, employment and availability of jobs, government fiscal budgets, and competitiveness of the economy or sector within a globalizing market. It is important to fully understand all three aspects of SD—economic, environmental, and social.

Environmental impacts include those occurring in local areas on air, water, and land, including the loss of biodiversity. Virtually, all forms of energy supply and use and land-use change activity cause some level of environmental damage. The emission of greenhouse gases is often directly related to the emissions of other pollutants, either airborne, e.g., sulfur dioxide from burning coal which causes local or indoor air pollution, or waterborne, e.g., from leaching of nitrates from fertilizer application in intensive agriculture.

The social dimension includes issues such as gender equality, governance, equitable income distribution, housing and education opportunity, health impacts, and corruption. Most mitigation options will impact one or more of these issues, and both benefits and tradeoffs are likely.

Mitigation options in the energy sector may be classified into those that improve energy efficiency and others that reduce the use of carbon-intensive fuels. The latter one may be further classified into domestic and imported fuels. Table 1 shows the synergies and tradeoffs of these options with economic, local environmental, and social sustainable development goals. In the case of energy efficiency, it is generally thought to be cost effective and its use reduces or eliminates local pollutant emissions. Improving energy efficiency is thus a desirable option in every energy demand and supply sector.

Energy use—buildings, transport, and industry sectors

In the buildings sector, energy efficiency options may be characterized as integrated and efficient designs and siting, including passive solar technologies and designs, and urban planning to limit heat island effect. Considering energy efficiency as the guiding principle during the construction of new homes results in both reduced energy bills—enhancing the affordability of increased energy services—and GHG abatement. Policies that actively promote integrated building solutions for both mitigating and adapting to climate change are especially important for the buildings sector. Good urban planning, including increasing green areas as well as cool roofs in cities, has proven to be an efficient way to limit the heat island effect, which also reduces cooling needs. Mitigation and adaptation can therefore be addressed simultaneously by the aforementioned energy efficiency measures.

Over the last decade, quantification of the progress toward sustainable development has gained ground. In the buildings sector, several thousand commercial buildings have been certified by the US Green Building Council's program on Leadership in Energy and Environmental Design, which uses 69 criteria to award certificates at various levels of achievement. The certification ensures that a building meets largely quantitative criteria related to energy use, indoor air quality, materials and resource use, water efficiency, and innovation and design process (http://www.usgbc.org ; USGBC (US Green Building Council) 2005). Economic and ethical considerations are the most cited reasons by businesses in the use of these two guidelines.

In developing countries, efficient cook stoves that use clean biomass fuels are an important option. These can have significant health benefits including reduction in eye diseases, the incident of which is disproportionately high among rural women in many developing countries where fuel wood and other biomass materials are a principal source of energy (Porritt 2005). It has also been shown, for example, that the availability of cleaner burning cookers and solar cookers in developing countries not only has important health benefits but also significant social benefit in the lives of women in particular (Dow and Dow 1998). A move to a more reliable and cleaner fuel not only has benefits in terms of carbon emission and health but also has the effect of freeing up significant amount of time for women and children which can then be applied to more socially beneficial activities, including going to schools in the case of children. The air pollution benefits of improved stoves is controversial, however, as other studies have noted that efficiency was improved at the expense of higher emissions of harmful pollutants.

Table 1 Sectoral mitigation options and sustainable development (economic, local environmental, and social) considerations: synergies and tradeoffs

Sector and mitigation options	**Potential SD synergies and conditions for implementation**	**Potential SD tradeoffs**
Energy supply and use		
Energy efficiency improvement in all sectors (buildings, transportation, industry, and energy supply)	Almost always cost-effective, reduces or eliminates local pollutant emissions and consequent health impacts, improves indoor comfort and reduces indoor noise level, creates business opportunity and jobs, and improves energy security Government and industry programs can help overcome lack of information and principal agent problems Programs can be implemented at all levels of government and industry Important to ensure that low-income household energy needs are given due consideration and that the process and consequences of implementing mitigation options are, or the result is, gender neutral	Indoor air pollution and health impacts of improving biomass cook stove thermal efficiency in developing country rural areas are uncertain
Fuel switching and other options in the transportation and buildings sectors	CO_2 reduction costs may be offset by increased health benefits Promotion of public transport and nonmotorized transport has large and consistent social benefits Switching from solid fuels to modern fuels for cooking and heating indoors can reduce indoor air pollution and free time for women in developing countries Institutionalizing planning systems for CO_2 reduction through coordination between national and local governments is important for drawing up common strategies for sustainable transportation systems	Diesel engines are generally more fuel efficient than gasoline engines and thus have lower CO_2 emissions, but increase particle emissions Other measures (CNG buses, hybrid diesel-electric buses and taxi renovation) may provide little climate benefits

Table 1 (Cont) Sectoral mitigation options and sustainable development (economic, local environmental, and social) considerations: synergies and tradeoffs

Replacing imported fossil fuel with DAES	Important to ensure that DAES is cost-effective Reduces local air pollutant emissions Can create new indigenous industries (e.g., Brazil ethanol program) and hence generate employment	Balance of trade improvement is traded off against increased capital required for investment Fossil fuel-exporting countries may face reduced exports Hydropower plants may displace local populations and cause environmental damages to water bodies and biodiversity
Replacing domestic fossil fuel with IAES	Almost always reduces local pollutant emissions Implementation may be more rapid than DAES Important to ensure that IAES is cost-effective Economies and societies of fuel-exporting countries would benefit	Could reduce energy security Balance of trade may worsen but capital needs may decline

Source: Sathaye et al. (2007)

DAES domestic alternative energy sources, IAES imported alternative energy sources

In the transport sector, the energy efficiency measures may be categorized into those that are vehicle specific and others that address transportation planning. Vehicle specific programs focus on improvement to the technology and vehicle operations. Planning programs are targeted toward street layouts, pavement improvements, lane segregation, and infra-structural measures that improve vehicle movement and facilitate walking, biking, and the use of mass transport. Cost-effective mitigation measures of both types have been identified that result in higher vehicle and/or trip fuel economy and reduce local air pollution. Institutionalizing planning systems for CO_2 reduction through coordinated interaction between national and local governments is important for drawing up common strategies for sustainable transportation systems. While there are many synergies in emission controls for air pollution and climate change, there are also tradeoffs. Promotion of bicycling, walking, and other nonmotorized modes of transportation has large and consistent cobenefits of GHG reduction, air quality, and people health improvement. Diesel engines are generally more fuel efficient than gasoline engines and thus have lower CO_2 emissions, but increase particle emissions. Air quality-driven measures, like obligatory particle matter and NOx filters and in-engine measures, mostly result in higher fuel use and consequently higher GHG emissions.

In the industrial sector, energy efficiency options may be classified as those aimed at mass-produced products and systems and those that are process specific. The potential for cost-effective measures is significant in this sector. Measures in both categories would have a positive impact on the environment. To the extent, the measures improve productivity; they would increase economic output and hence add to government tax revenue. Higher tax revenue would benefit national, state, and local government fiscal balance sheets (Nadel et al. 1997; Barrett et al. 2002; Phadke et al. 2005).

In the industrial sector, several trade associations provide platforms for organizing and implementing GHG mitigation programs. Performance indicators are being used by the aluminum, semiconductor, and cement industry to measure and report progress toward SD. The Global Reporting Initiative, a United Nations Environment Programme Collaborating Centre initiative, for example, reports that over 700 companies worldwide make voluntary use of its Sustainability Reporting Guidelines for reporting their SD achievements. Industrial sectors with high environmental impacts lead in reporting and 85% of the reports address progress on climate change (GRI (Global Reporting Initiative) 2005)and (KPMG Global Sustainability Services 2005).

Since energy efficiency improvement reduces the reliance on energy supply, it is likely to improve a nation’s energy security. Using prices as an instrument to promote energy efficiency mitigation options is often difficult due to the many barriers that impede their progress. Lack of information about such mitigation options and the principal agent problem have been documented to be particularly significant barriers in the residential sector, but these also prevail in the small and medium scale industries sectors (Sathaye and Murtishaw 2005). Programs that can overcome such barriers would increase energy efficiency penetration.

Energy supply

Switching to low carbon energy supply sources is the other mitigation category in the energy sector with significant GHG benefits. This can be achieved through either increased reliance on imported or indigenous alternative fuels. Using a higher proportion of low carbon imported fuels will almost always reduce local air pollution. Its direct impact will be to increase payment for fuel imports that may result in worsened balance of payments unless these are utilized to increase a nation’s exports (Sathaye et al. 1996). The higher fuel imports will increase dependence on international fuel supply that may result in reduced energy security unless diversification of supply mitigates concerns about increased dependence. Economies and societies of low carbon fuel exporting countries would benefit from the higher trade.

Increased reliance on most indigenous low carbon energy sources[4] would also reduce local air pollution although the local environmental benefits in certain solid biofuel applications appear to be uncertain. While indigenous low carbon fuels can reduce fuel imports, these have to be balanced against higher capital requirements for investment in the extraction, processing, and delivery of fuel (Sathaye et al. 1996). The development of large hydro life cycle inventory (LCI) sources can displace local populations and put their livelihood in jeopardy, and in reservoirs with large surface area, the resulting methane emissions may reduce their net GHG benefit substantially. For example, although hydroelectric plants have the potential of reducing greenhouse emissions significantly, there is a large environmental literature that points to important environmental costs (McCully 2001; Dudhani et al. 2005), highlights the social disruptions and dislocations (Sarkar and Karagoz 1995; Kaygusus 2002), and also questions the long-term economic benefits of major hydropower development. Increased use of indigenous LCI fuels can reduce export of fuels from other countries to the extent the latter ones are substituted away. These may adversely affect the trade balance of exporting countries (Sathaye et al. 1996).

At the same time, low carbon fuels can have other environmental benefits. For example, a move away from coal to cleaner fuels will reduce ecosystem pressures that often accompany mining operations (Azapagic 2004). Similarly, a move away from charcoal and fuel wood as a source of energy will have the attendant environmental benefits of reducing the pressures of deforestation (Masera et al. 2000; Najam and Cleveland 2003). This points toward the need to optimize technology choice decisions not only along the dimension of carbon emissions but also other environmental costs.

Wind power can cause harm to bird populations and may not be esthetically appealing. Increased use of biomass is viewed as a renewable alternative, but indoor air pollution from solid fuels has been ranked as the fourth most important health risk factor in least developed countries. Tradeoffs among pollutants are inevitable in the use of some mitigation options and need to be resolved in the specific context in which the option is to be implemented.

IPCC (2007) documents several examples of corruption that either increases the price of electricity and/or prevents the use of proceeds from extracted resources to meet development needs. This suggests that corruption may reduce the SD benefits of new mitigation technologies and/or low carbon fuels that require a significant modification of social systems.

Cross-sectoral impacts

The implementation of mitigation options often creates new industries, e.g., for energy efficient products like cook stoves, efficient lamps, insulation materials, heat pumps, efficient motors, etc. or for solar panels, windmills, biogas installations, etc. The success of these new industries depends on various factors, such as the degree of information, costs, the image of the product, and its traditional competitors or its attributes other than being energy efficient. New industries can create new jobs and income and might be pioneers in new market with significant competitive advantage. Ethanol production from sugar waste has created a new industry and generated employment opportunities and tax revenue for the government of Brazil. On the other hand, the older outpaced industry may lose jobs. Besides the uncertainty on the overall net effect, this may lead to regional loss of employment. For example, the increased production of biofuels for transportation, or energy production in rural areas, is expected to protect existing employment and to create new jobs in rural areas (Sims 2003). Renewable energy systems are more labor intensive than fossil fuel systems and a higher proportion of the jobs are relatively highly skilled. Thus, an increase in employment of the rural people can only be achieved, if

[4] LCI energy sources include hydro, biomass, wind, natural gas, and other similar energy carriers.

corresponding learning opportunities are created. If, however, labor intensity decreases over time, the long-term effect on jobs might be less pronounced than originally anticipated.

Mitigation and adaptation synergies and tradeoffs

Mitigation and adaptation are linked in several ways. Over the long-term less mitigation implies more adaptation. This is relevant when developing plans for long-lived infrastructure, such as sea protection walls. It is less relevant for most other forms of adaptation, since climatic impacts are only projected to diverge after several decades. For several reasons, mitigation and adaptation policies have been developed separately. Adaptation often has short-term benefits at local scales in terms of decreasing vulnerability to current climate variability; the benefits of mitigation in terms of avoided climate impacts will develop over larger temporal and spatial scales (although often short-term cobenefits exist). Maybe more important from a practical point of view: The economic sectors most important for mitigation (energy, industry, transport) are different from those important for adaptation (water and land management, coastal protection, health care).

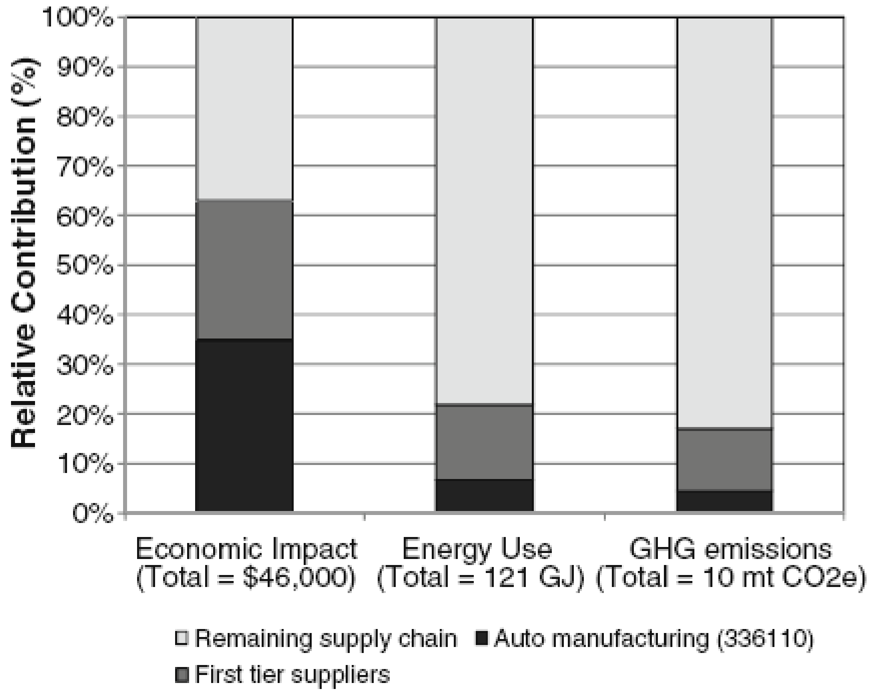
In recent decades, the emphasis of the climate debate focused mainly on mitigation. Only recently, adaptation has received increasing political and scientific attention, triggered by an increasing number of observed climatic impacts and the increasing recognition that—even if successful—climate mitigation cannot avoid all impacts. This has also increased the interest in integrating adaptation and mitigation policy options: Policy separation increases the risks of tradeoffs and can lead to missed opportunities for synergies.

Because synergetic options are to be found mainly in a limited number of sectors, their combined potential to make a dent in global greenhouse gas emissions trends is limited. But for local and regional investment decisions, they can be important, especially for developments with a strong spatial component. In forestry and soil management, the vulnerability of land can be decreased and carbon stocks protected at the same time. In construction, design of buildings and urban areas can take into account both energy efficiency and thermal comfort. Water management plans can combine hydropower with water retention for drought periods. But if adaptation takes place without considering greenhouse gas emissions, tradeoffs can result. Important examples are increased cooling, increasing irrigation, and energy consumption through protective infrastructure. For renewable energy, both synergies and tradeoffs can be relevant. Biofuels or hydropower can be sensitive to changing precipitation. Renewable decentralized energy systems can avoid supply problems that may occur in very much centralized power systems in flood-or storm-prone areas.

It is often argued that adaptation and mitigation should be mainstreamed into sector policies. The examples above demonstrate that both approaches to climate change should be taken into account simultaneously in the development of sector policies. This implies the establishment of institutional links between the now often disparate policy domains.

Role of governance

The broad message of the IPCC Fourth Assessment Report, reinforced in the previous sections, is that significant opportunities exist to change development pathways toward lower emissions through energy efficiency. But it is also that this will require paying careful attention to the cultivation of institutional conditions in which such gains can be harnessed (Sathaye et al. 2007). Large-scale improvements in energy efficiency require the creation of institutional conditions that can facilitate, reward, and accelerate such improvements. Importantly, such conditions need to be created within government, civil society, and market institutions and in the interactions between the three (Davis 1999; Rayner and Malone 2000;OECD 2001; Najam et al. 2004).



Sources: Derived from Hendrickson et al. (2006) and CMU (2008).

Fig. 4 Economic impact, energy use, and GHG emissions associated with the manufacture of a midsize US passenger car (excluding vehicle fuel use)

Government

The choice of policies that governments seek and are able to pursue is influenced by the political culture and regulatory policy style of a country or region and the extent of public expectations that their governments will take a strong or weak lead in pursuing policy responses. An important, though often neglected, issue in the choice of policy instruments is the institutional capacity of governments to implement the instrument on the ground (Rayner 1993). This is often a matter of what countries with highly constrained resources think that they can afford. However, even industrialized nations exhibit significant variation with respect to the characteristics that would be considered ideal for the successful application of the complete suite of policy instruments listed above. These attributes include (O'Riordan et al. 1998):

- A well-developed institutional infrastructure to implement regulation
- An economy that is likely to respond well to fiscal policy instruments because it possesses certain characteristics of the economic models of the free market
- A highly developed information industry and mass communications infrastructure for educating, advertising, and public opinion formulation
- A vast combined public and private annual RD&D budget for reducing uncertainties and establishing pilot programs

The implication of the above is that not only do we need an understanding of the "fit" of a particular policy instrument to a particular efficiency problem but also we need to understand the "fit" of that instrument with the particular institutional temperament of the concerned governments.

Table 2 Electricity use and motor system electricity savings potentials of selected sectors in the manufacture of a midsize US passenger car

Input-Output Description sector	Total electricity use (kWh)	Motor system electricity use (kWh)	Motor system efficiency potential (%)	Potential electricity savings (kWh)
336110 Automobile and light truck manufacturing	727	313	15	47
Auto manufacturer total				*47*
Selected major suppliers (direct and indirect)				
336300 Motor vehicle parts manufacturing	1,283	552	15	83
331111 Iron and steel mills	681	341	12	41
331312 Primary aluminum production	574	80	12	10
331510 Ferrous metal foundries	215	71	12	9
325180 Other basic inorganic chemical manufacturing	130	74	16	12
32721A Glass and glass products, except containers	102	33	15	5
325211 Plastics material and resin manufacturing	89	51	16	8
334413 Semiconductors and related device manufacturing	86	28	23	6
325190 Other basic organic chemical manufacturing	85	48	16	8
326210 Tire manufacturing	65	34	15	5
Total for selected suppliers				*186*

Sources: Derived from Hendrickson et al. (2006), CMU (2008), and US DOE (2002, 2007)

Market

Industry is a central player in ecological and sustainability stewardship. Accordingly, over the past 25 years or so, there has been a progressive increase in the number of companies taking steps to address sustainability issues (Holliday et al. 2002; Lyon 2003) at either the company or industry level. An increasing number of companies are focusing on energy efficiency, for its economic payoffs as well as its emissions savings. Some of the more widely acknowledged corporate sustain-ability drivers include regulatory compliance, market opportunities, and reputational value. Lyon (2003) hypothesizes that voluntary action on the environment might be explained by either a recognition by companies that pollution is a symptom of production inefficiencies, or a perception that consumers are willing to pay more for products with better environmental credentials. Either explanation would signal that markets are as important as regulation as an incentive for improved environmental performance, particularly in the context of energy efficiency gains that come at the firm or consumer level.

Companies have begun to recognize that pursuing sustainability offers potential cost savings (Thompson 2002; Dunphy et al. 2003). For example, by increasing energy and material efficiency in production and by reducing wastes, companies can reduce costs per unit of production and thereby gain a competitive market advantage (Schaltegger et al. 2003). This concept of “eco-efficiency” further acknowledges that businesses which constantly work to evaluate their environmental performance will be more innovative and responsive businesses. One example of business being able to meet both its economic and ecological goals through energy efficiency is CEMEX, a Mexican-based cement manufacturer. One of the major environmental issues facing cement manufacturers is energy use (Wilson and Change 2003). As part of its sustainability strategy, Cemex focused intently on its energy use in an effort to reduce its ecological burden. For example, in 1994 CEMEX embarked on an ecoefficiency programs to “optimize its consumption of raw materials and energy” (Wilson and Change 2003, p.29). Through this and other measures, CEMEX reduced CO_2 emissions 2.7 million tons between 1994 and 2003 (Wilson and Change 2003, p.32).

Importantly, notions of corporate social responsibility (CSR) have gained a wider hold and energy efficiency is a central tenet within CSR implementation (Box 1). The arguments in support of CSR include competitive advantage (Porter and Kramer 2002), notions of corporate citizenship (Andriof and McIntosh 2001), and stakeholder theory (Driscoll and Starik 2004;Windsor 2004; Fig. 4;Table 2).

Civil society

Civil society refers to the arena of uncoerced collective action around shared interests, purposes, and values (Rayner and Malone 2000). During the past three decades, the mantle of civil society has been increasingly claimed by nongovernmental organizations (NGOs). Nongovernmental organizations have been particularly active and often influential in shaping societal debate and policy directions on climate change (Corell and Betsill 2001; Gough and Shackley 2001).

The literature on the various ways in which civil society and especially NGOs influence global environmental policy in general and climate policy, in particular, points out that civil society employs “civic will” to the policy discourse and that it can motivate policy in three distinct but related ways (Banuri and Najam 2002). First, it can push policy reform through awareness raising, advocacy, and agitation. Second, it can pull policy action by filling the gaps and providing policy services such as policy research, policy advice, and, in a few cases, actual policy development. Third, it can create spaces for champions of reform within policy systems so that they can assume a salience and create constituencies for change that could not be mobilized otherwise.

The image of civil society “pushing” for environmental protection and climate change mitigation policies is the most familiar one. Governments have eventually began responding to these calls from civil society for systematic environmental protection and climate change mitigation policies, but so have businesses and individual consumers (Gough and Shackley 2001; Najam et al. 2004). The role of civil society in “pulling” climate change mitigation policy through energy efficiency gains is also significant. In both the USA, Europe, and in some developing countries, citizen groups have led the call for improved energy efficiency not only by demanding others to adopt such policies but by becoming exemplars of improved and efficient practices themselves. Finally, civil society plays a significant role by “creating spaces for champions of policy reform” and providing platforms where these champions can advance these ideas. The Pew Climate Initiative and the Millennium Ecosystem Assessment are two examples of how civil society has created forums and space for discourse by different actors.

Box 1: Supply Chain Energy and Carbon Emissions Management

In a recent expansion of CSR, many manufacturers are beginning to investigate and take responsibility for the so-called energy and carbon "footprints" of their products. Although definitions vary, in general the terms "energy footprint" and "carbon footprint" refer to the total energy use and carbon emissions associated with a product across its entire life cycle, from production to disposal. Much recent activity in this area has been driven by two of the world's largest retailers –Wal-Mart (U.S.) and Tesco (UK) – which have launched initiatives to compile carbon footprint data from a number of their key product suppliers, some of which are among the world's largest manufacturing companies (Mui 2007; Specter 2008). Other examples include companies in the bottled water, footwear (Cortese 2007), and wine making industries (Snow 2008).

The process of estimating energy and carbon footprints forces a manufacturer to look beyond its own operations and critically examine the practices of its suppliers. Such examinations can reveal supply chain energy use and GHG emissions far greater than the energy use and GHG emissions associated with a manufacturer's own operations. Figure 4 illustrates this phenomenon for the manufacture of a midsize passenger vehicle in the United States (Hendrickson et al. 1998, Hendrickson et al. 2006; CMU 2008).

Figure 4 suggests that the U.S. auto industry is only directly responsible for a small fraction of the energy and carbon footprints associated with the manufacture of the typical midsize passenger vehicle, even when first-tier suppliers (which are often closely linked to auto manufacturing companies) are considered. Similar phenomena have been demonstrated for a variety of products with extensive supply chains. For example, Williams (2004) found that in manufacture of a typical personal computer (PC), less than five percent of the total supply chain energy use was associated with the final assembly operations of the PC manufacturing company itself.

Thus, the importance of supply chain management in manufacturing energy efficiency improvement initiatives is self-evident. This point is underscored with an example in Table 2, which presents potential electricity savings associated with hypothetical supply chain motor system efficiency improvements in the midsize U.S. passenger vehicle manufacturing case study from Figure 4. The third column in Table 2 shows the total electricity use associated with the auto manufacturing sector itself (336110) and ten of its top direct and indirect supplier sectors (CMU 2008). The results suggest that potential motor electricity savings among ten of the auto industry's major suppliers is around four times greater than the electricity savings that the auto industry might realize in its own facilities.

Although many companies are pursuing energy and carbon footprint initiatives, there is an ongoing debate over whether such footprint data should ultimately be communicated in the marketplace via product carbon footprint labels to help inform consumer purchasing decisions. Questions remain about the wisdom of carbon footprints as singular environmental metric, the transparency and reporting of data, consumer demand for such labels, and conformance with international life-cycle assessment standards (Pant et al. 2008; Green and Capell 2007). It is also not yet clear the extent to which supply chain data availability, collection, and manipulation issues may affect the validity and comparability of carbon footprint estimates (Minx et al. 2007). However, nascent carbon footprint standards efforts are emerging to consider such issues (BSI 2008). Regardless of whether energy and carbon footprints are ultimately communicated to consumers, as internal corporate environmental management tools, energy and carbon footprints hold great promise for exposing and pursuing significant efficiency opportunities across the supply chain for many products.

Institutional interactions

A final point that needs to be made about the institutional conditions for energy efficiency improvements related to the interplay between the institutions of the three sectors discussed here—governments, markets, and civil society. Because improved energy efficiency requires multiple actions from multiple actors at multiple levels—from global governance to national governments, to firms and corporations, and to individuals—therefore we should look at also the interactions between these various actors. Indeed, compartmentalizing our understanding of these institutions can be counter-productive because each is propelled by the other. Business, for example, needs (and sometimes demands) unambiguous and predictable regulations; consumers seek dependable and impartial knowledge to be able to make informed decision; civil society can put pressure on governments as well as businesses (but in very different ways) to seek change in policy or practice. This is not the place to discuss the network of interactions between these actors, but it is important to highlight the findings of the literature which is now looking at each institution fulfilling its own role as best as it can— government, through regulation; business through its profit motive; and civil society as a shaper and a voice of social aspirations (Najam et al. 2006).

Summary and conclusions

Changing development paths will be critical to stabilizing climate change because research to date shows that climate mitigation alone will not solve the climate problem. This will require that development be made more sustainable, i.e., address both its local and global deleterious impacts. Historical data at the global and country level illustrate that it is indeed possible decouple economic growth from energy use and carbon emissions. An important step in this regard would be to identify relevant nonclimate policies in every sector including trade, finance, rural and urban development, insurance, and forestry. Examples from the past suggest that sectors far away from their production frontier may have more opportunities than sectors that are close to the production frontier to adopt policies that bolster growth, meet other sustainable development goals, and reduce GHG emissions relative to baseline. Past experience also suggests that shifting development paths toward less carbon-intensive trajectories usually results from an array of coordinated policies and measures that are sustained over time and not from a single one-off decision in one sector. Thus, such steps will, of necessity, be context specific and will work only within local and national contexts.

Mitigation options in the energy sector can be synergistic or create tradeoffs between carbon emissions reduction and other sustainable development criteria. Synergies and tradeoffs also exist between mitigation and adaptation approaches to climate change and capacity building, which suggests that the two should be considered simultaneously in the development of sector policies. This implies the establishment of institutional links and a governance structure between the now often disparate policy domains of government, business, and civil society. In the last few years, industry and other businesses are beginning to investigate and take responsibility for their carbon and energy "footprints". Communicating the footprint data in a reliable manner to help inform consumer purchase decisions is still being debated. The way forward requires that development choices that display synergy between climate mitigation and adaptation and local sustainable development characteristics be identified, evaluated, and mainstreamed in order to make development more sustainable.

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Appendix: Brazil and South Africa energy efficiency program examples

Energy efficiency policy choices have shown to have a significant impact on energy trends, social progress, and environmental quality in developing countries (Geller et al. 2004). In the case of Brazil, programs and measures have included not only improvements in the energy supply and demand side management but also specific tax incentive polices encouraging the production of cheaper goods to allow industry to increase their production (and create more jobs while increasing its profits) and to make those goods more accessible to lower-income sectors of the population. In this vein, two examples are worth noting here: (1) The National Electricity Conservation Program (Procel) and (2) The One-Liter-Engine (1-l) Automobile Program. These policies, aside from their original objectives, have also led to lower carbon dioxide emissions than would otherwise have been the case.

1. Procel: From December 1985, when it was created, until 2006, Procel invested some US $500 million and achieved energy savings estimated at 25,000 GWh/year, equivalent to some 6,600 MW of installed capacity, with clear economic benefits in terms of avoided costs and avoided

emissions (Schaeffer et al. 2008). Promoting end-use electricity efficiency and transmission and distribution loss reduction, the Procel program funds or cofunds a wide range of energy efficiency projects focused mainly on research, development, and demonstration; education and training; testing, labeling, and standards; marketing and promotion; private sector support; utility demand-side management programs; and direct implementation of efficiency measures and technical support (Szklo et al. 2005b). The Procel program has also advocated for more than 15 years mandatory efficiency standards for household appliances, lighting products, and motors sold in Brazil (Garcia et al. 2007).

2. One-liter Engine Automobile Program: In 1993, a tax incentive was introduced in Brazil encouraging the production of small-engine automobiles (<1,000 cc). This cut in the tax on industrialized products (IPI) was intended to encourage the output of more efficient automobiles that were accessible to lower-income sectors o the population. By 2001, almost three quarters of domestic sales of new automobiles consisted of 1-l engine automobiles, with some five million 1-l engine vehicles on the road in Brazil in 2000, produced from 1993 onward. As 1-l engine automobiles use less fuel than vehicles with more powerful engines, the reduction in the IPI tax also resulted in abatement in CO_2 emissions, estimated at 1.2 MtC in 2000 alone and1.4 MtCin2001(Szkloetal. 2005a). On the other hand, more stringent environmental quality specifications for oil products worldwide are tending to step up energy use and, consequently, CO_2 emissions at refineries. In Brazil, for example, the stipulated reduction in the sulfur content of diesel and gasoline between 2002 and 2009 should increase the energy use of Brazil's refining industry by around 30%, with effects on its CO_2 emissions. Thus, the world refining industry must deal, on some occasions, with tradeoffs between emissions of pollutants with local impacts (due to fuel specifications) and emissions of pollutants with global impacts (due to the increased energy use at refineries to remove contaminants from oil products), although promising technological options do exist that could ease this clash in the near-to-mid term (e.g., the reduction per se of the energy use at the refinery and the development of treatment processes using nonhydrogen consuming techniques; Szklo and Schaeffer 2007).

South Africa in 2008 started experiencing serious electricity shortfalls and load shedding. Remarkably, there is significant overlap between responses to that short-term crisis and plans for dealing with the long-term crisis of climate change. Long-term mitigation scenarios for South Africa identified various strategic options. The near-term strategy was labeled "Start Now" and is dominated by energy efficiency interventions. Industrial energy efficiency in particular can provide some of the greatest emission reductions of all technical options considered (Winkler 2007). Efficiency in the commercial, residential, and transport sectors all provide negative-cost mitigation as well, saving more over the life of the intervention than the initial costs.

Many specific technologies considered in response to mitigation and to electricity shortages are the same—compact fluorescent lamps, geyser blankets, efficient buildings, smart metering, energy management systems, and more. R 2 billion is to be spent on a range of programs, including efficient use of electricity, generation from renewable sources, conservation of electricity, and cogeneration. In addition, South Africa's Treasury Department will consider reform of the existing vehicle taxes to encourage fuel efficiency.

These individual measures are clearly understood as part of a bigger change—shifting the South African economy from its energy—intensive past to greater energy efficiency. That greater energy efficiency is good for sustainable development and is noted in that it will be positive for job creation, the top policy priority—with a cobenefit of reducing GHG emissions.

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