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Co-impacts of energy-related climate change mitigation in Africa's least developed countries: The evidence base and the research needs

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Abstract

This article analyses the debate associated with the co-impacts of climate change mitigation in developing countries, with a particular focus upon Africa's least developed countries. While these countries' emissions of greenhouse gases are relatively small (and they do not have emission limitation commitments in the current international regime), inattention to the mitigation agenda would mean that developing countries both miss potential funding opportunities and fail to 'climate-proof' their development strategies. A focus, therefore, upon the short-term, local, developmental impacts that serve to change the relative attractiveness of different mitigation options from the perspective of the developing country is in these countries' current strategic interests. In this article, I examine three energy-related climate change mitigation options: improved cookstoves, carbon-free electricity and improved energy efficiency in industry. Following a conventional 'climate analysis' of each, the potential co-benefits and co-costs – drawn from the general literature and then investigated more specifically for the African countries under scrutiny – are identified. This examination reveals that relatively little work focusing explicitly, and simultaneously, upon climate change mitigation and co-impacts has been carried out in Africa's least developed countries. In conclusion, a call for cross-fertilisation of information between heretofore disparate research communities is made. Additionally, the development of an integrated research agenda is identified as a priority, and the basis of this agenda is articulated.

Keywords

developing countries; climate change mitigation; co-impacts; co-benefits; energy services.

1. Introduction

The purpose of this paper is to analyse the debate associated with the co-impacts of climate change mitigation in developing countries, with a particular focus upon Africa's least developed countries.[1] I aim to present the state of the debate on the issue, as well as to identify priorities for research, moving forward.

To set the context, note first of all three important facts about global climate change and Africa's least developed countries: i) these countries continue to contribute minimally to net emissions of greenhouse gases; ii) they have no emission limitation commitments in the global regime; and iii) they are amongst the countries that are most affected by global climate change. Let me briefly expand upon each of these points.

First, net greenhouse gas emissions from Africa's poorest countries are relatively small – indeed, given the carbon sequestration capacity of some of these countries, some national net emissions figures may actually be negative. To illustrate, consider Ethiopia, which, with 80.7 million people (World Bank, 2010a), is the most populous of the countries under investigation. Ethiopia's net greenhouse gas emissions – as reported in the country's national inventory report to the United Nations Framework Convention on Climate Change (UNFCCC) Secretariat – amounted to 99,749.7 Mt CO_2e in 1994.[2] Dominant sectors were 'carbon dioxide emissions from biomass', which accounted for two-thirds of the net contribution, and 'land-use change and forestry', which served as a net sink. With a population of 53.5 million in 1994 (Federal Democratic Republic of Ethiopia, 2001, 3), per capita emissions amounted to 1.86 tonnes CO_2e at that time. Similarly, net per capita emissions from the next three most populous countries under investigation in our study[3] – namely, the Democratic Republic of Congo (0.17 tonnes CO_2e), Sudan (3.57 tonnes CO_2e) and Tanzania (1.95 tonnes CO_2e) – were all well below the global average of 6.00 tonnes CO_2e.[4]

Second, developing countries do not have emission limitation obligations in the global climate change regime. While it is recognised that all countries should participate 'in an effective and appropriate international response', this is tempered by the caveat, 'in accordance with their common but differentiated responsibilities and respective capabilities and their social and economic conditions' (UNFCCC, 1992, Preamble). Hence, the legally-binding mitigation commitments laid out in the Kyoto Protocol to the UNFCCC apply only to developed countries.

And third, developing countries are the ones that are most vulnerable to global climate change (UNCTAD, 2009, 137; World Bank, 2009). With relatively limited 'adaptive capacity' – given problems with their health systems and infrastructure, associated with their modest institutional abilities to manage complexities – these countries will find it particularly challenging to handle the shifts catalysed by global climate change (Boko et al, 2007; UNCTAD, 2009, 138).

Thus, given these three realities, one can immediately query the wisdom of considering climate change mitigation in Africa's least developed countries. By contrast, anything that might serve to divert attention from the importance of climate change adaptation could be seen as naive, if not downright dangerous (compare with Tol, 2005).

But, in truth, neglect of the topic would itself be imprudent. Indeed, scientific developments reveal that greenhouse gas emission limitations must eventually occur worldwide; 80% global cuts demand this (Meinshausen et al, 2009). While various interpretations of 'fairness' would allocate emission caps and – inevitably – emission cuts differently across various developing countries (Baer et al, 2008; Chakravartya et al, 2009), there is no escaping the fact that greenhouse gas emission restrictions must be underway in all developing countries within a generation. Additionally, there are two key pro-poor reasons for devoting some attention to the mitigation agenda right now.

One reason is positive. Growing activity in international carbon markets (financing opportunities through both the Clean Development Mechanism and the voluntary markets) and the continuing follow-up to the Copenhagen Accord suggest that funders will be increasingly exploring mitigation options in the developing world. (For more on this issue, see, for example, Bredenkamp and Pattillo, 2010; and Bryan et al, 2009.) Many of these funders are primarily motivated by net greenhouse gas emissions reductions, prioritising projects that pursue the least-cost carbon reductions, irrespective of broader impacts.[5] It is not clear, however, whether the cheapest greenhouse gas emission reduction options are also the ones that will bring the most developmental benefits. In the face of such uncertainty, now is the time to gather the evidence, so that developing countries are well-placed to pursue mitigation options that are consistent with their own goals (compare with Nemet et al, 2010, 4; and Rai and Victor, 2010, 13). Without such knowledge, the negotiations over specific climate projects will be driven by others.

And the other reason is negative. If decarbonisation becomes a global priority, then those who have adopted a low-carbon strategy for development will be able to prosper – they will have ready access to export markets, particularly for their goods and services that have proved innovative in advancing 'green growth'. By contrast, for those who have not adopted a low-carbon strategy for development, not only will such export markets not materialise, but their production, more broadly, will be labelled 'carbon-intensive' and thus be potentially susceptible to border adjustments in world markets (van Asselta and Brewer, 2010); hence, their competitiveness in this new world will be low. More generally, decisions made now have the potential to 'lock-in' outcomes (be they high-carbon or low-carbon) for many years to come.[6]

Work in this area is urgently needed, and calls for such investigations have been forthcoming. In 2007, for instance, Sims et al (2007, 254) argued that, 'Sustainable energy systems emerging as a result of government, business and private interactions should not be selected on cost and [greenhouse gas] mitigation potential alone but also on their other co-benefits.' But that call has not usually been heeded. While work on priorities in terms of greenhouse gas emission reductions continues – the increasing availability of marginal abatement cost curves attest to this (e.g., Akimoto et al, 2010; and Bole et al, 2009, each of whom examine a broad cross-section of countries; McKinsey & Company, 2009 look more generally) – the developmental impacts of the same have received much less attention. The Clean Development Mechanism (CDM) would seem to be a natural source of insight, given its obligation to consider the 'sustainable development impacts' of climate change mitigation activities, but its proceedings have fallen short of expectations (Bumpus and Cole, 2010; UNCTAD, 2009, 160-161; WAC, 2009, 3). As Karakosta et al (2009, 77) observe, 'Actual CDM practice, however, has shown that such projects are largely initiated by the demand for relatively low-cost Certified Emission Reductions (CERs), leading to a series of ad-hoc projects, rather than serving the overall policy objectives of the host countries.' (See, as well, Bollen et al, 2009, 6; Mulugetta and Urban, forthcoming; and Sathaye et al, 2010.)

A focus upon Africa's least developed countries is also appropriate at this time. While the continent has largely been overlooked in climate financing to date, interest in the potential exists and is growing (Timilsina et al, 2010). Additionally, a well-respected African analyst on climate change remarks that, 'A better quantification of ancillary benefits that Africa could reap from [greenhouse gas] mitigation could constitute the ultimate incentive for Africa to take part in a global endeavour to stabilise [greenhouse gas] concentrations in the Earth's atmosphere' (Sokona, 2008, 9).

Given the pervasiveness of greenhouse gases throughout society, interest in mitigation – ultimately aimed at a virtual decarbonisation of society – necessarily directs attention to every corner of human activity.[7] With respect to Africa's least developed countries, two areas immediately rise up the agenda: i) energy-related projects; and ii) land use-related projects. I briefly elaborate upon each in turn.

With increased use of energy often identified as a necessary (though not sufficient) precondition for development, it is not surprising that developing countries' 'climate change mitigation plans' – included in the various 'national communications' that 'non-Annex I' countries have submitted and those identified under the terms of the Copenhagen Accord – have been prominent. Of our 34 countries under examination, virtually all have submitted at least one National Communication,[8] and nine have submitted a communication as part of the Copenhagen Accord process.[9] As but one example of the latter, the submission from the Ethiopian Government identifies the following as its priorities: renewable electricity for the grid; bio-fuel development for road transport and for household use; renewable electricity for off-grid and direct use; renewable electricity for trains; forestry; agriculture; and waste management (Federal Democratic Republic of Ethiopia, 2010). Though not exhaustively energy, the relative rankings may be suggestive. Moreover, notwithstanding the project eligibility restrictions upon CDM activities to this time (Paulsson, 2009) – and the criticisms of the Mechanism more broadly – the reader's attention is directed to Table 1, where all those projects in our 34 countries that were part of the records on 1 July 2010 are listed. (Note that there are, in total, 2,635 projects in the database.) Though these nine projects cover a range of activities, the majority are energy-related.

Table 1 – CDM projects involving one of 34 selected African countries

Country	**Kind of project**	**Status**
Equatorial Guinea	Recovering flared gas to make methanol	Rejected
Ethiopia	Afforestation/reforestation	Registered
Mali/Senegal/Mauritania	Hydropower plant	Registered
Mozambique	Fuel switch (coal to natural gas) in a clinker manufacturing plant	Under review
Rwanda	Distribution of compact fluorescent light bulbs in the residential sector	Registered
Tanzania	Landfill gas recovery for electricity generation	Registered
Uganda	Hydropower plant (with HFO-fired genearator for peaking)	Registered
Uganda	Reforestation	Registered
Zambia	Improved stoves	Registered

Land use-related projects are often prominent in the aforementioned marginal abatement cost curves that have been completed in developing countries, generally, and in sub-Saharan

Africa more specifically. The oft-cited McKinsey study, for example, found that ‘terrestrial carbon’ options account for more than one-quarter of the most cost-effective mitigation options, globally; more than 90% of these were located in the developing world (McKinsey & Company, 2009). Turning to ‘Africa’ more specifically, ‘cost-effective’ abatement potential of 2.4 Gt CO_2e a year by 2030 is identified; this represents just over 6% of the global potential identified (McKinsey & Company, 2009, 154). A particularly preferable option for Africa includes mitigation of slash-and-burn agriculture (McKinsey & Company, 2009, 122); in the energy sector, ‘reduced flaring emissions will be the largest lever’, and waste management also offer abatement potential (McKinsey & Company, 2009, 72 and 93). Land-use related options, however, predominate most such list of options.

Collectively, then, energy and land-use emerge as particularly visible (compare with Stern, 2009, who highlights ‘forestry, agriculture and energy’). This article focuses upon the former – namely, selected energy-related climate change mitigation options. The co-impacts of land-use-related climate change mitigation options are being researched elsewhere, and that agenda is certainly to be encouraged (Brown, Seymour and Peskett, 2008; Dickson et al, 2009; Grantham Institute, 2009, 19; Sasaki and Yoshimoto, 2010, 7; Stickler et al, 2009).[10] Space limitations in a single article, however, encourage a focus upon a part of the broader mitigation agenda.

This article proceeds in four sections. Having set the context in this first section, I move on to the selected co-impacts for the identified energy-related mitigation options in the second section. In the third section, areas for research for the near-term are identified. And, finally, in the fourth section, the key points are summarised and conclusions are offered.

2. Co-impacts of energy-related mitigation options

In this section, I investigate three energy-related mitigation options that are relevant for many of Africa’s least developed countries.[11] For each, I describe it, and I then identify the ‘ideal evaluation’ that would be undertaken in order to complement a mitigation (greenhouse gas emission reduction) analysis with a developmental (co-impacts) analysis, focusing upon one specific – and potentially prominent – co-impact. I then proceed to review the state of knowledge – that is, I determine the extent to which this ‘ideal evaluation’ can presently be completed. I conclude by reviewing our confidence regarding the co-impacts and by identifying the evidence gaps.

2.1 Improved cookstoves

Across Africa, up to 90% of the rural population relies upon biomass to provide household energy services (compare with Hutton et al, 2007, generally). When combusted in cookstoves, this biomass generates carbon dioxide. Therefore, a key climate change mitigation option is to provide households with more-efficient cookstoves, so that the same level of energy service can be provided with less fuel burnt (and thus less carbon dioxide produced).

To evaluate fully any key co-impact associated with a climate change mitigation option, I need to draw upon the following information: i) the cost of a programme to carry out the particular mitigation activity; ii) the greenhouse gas emission reductions associated with this programme; and iii) characteristics of a key co-impact arising from the programme. While there has been significant work on each of these individual elements in the case of replacing cookstoves, relatively little has put all of the pieces together.

The performance of household cookstoves has been a concern of development studies since at least the 1960s, with interest waxing and waning during this period (Krugmann, 1988; von Schirnding et al, 2002, 22; Warwick and Doig, 2004). Today, however, cookstoves are receiving significant attention. This has been catalysed by the launch of the 'Global Alliance for Clean Cookstoves', which is supported by a number of high-profile agencies including the German and U.S. official development organisations, the United Nations Foundation, Morgan Stanley and Shell. Now is the time for concerted effort, the Alliance argues, because several factors are aligning 'as never before to put the sector within reach of a "tipping point" for adopting clean cookstoves at scale'. The work of the Alliance has prompted continued work into cookstoves' technologies and the means to deliver them at low cost (compare with Adkins et al, 2010; and Slaski and Thurber, 2009).

There has been some attention accorded this mitigation option in terms of overall climate strategies. When the Intergovernmental Panel on Climate Change (IPCC) reviewed a number of mitigation alternatives that were attractive in residential and commercial buildings in its Fourth Assessment Report, improved stoves were identified as one set of options – references to studies carried out in Mynamar and India were explicitly made (Levine et al, 2007, Table 6.2). In addition to these studies cited by the IPCC, there have been other investigations that have explicitly looked at the link between cookstove use and greenhouse gas emissions – Bailis et al (2003), for instance examined the greenhouse gas emissions associated with alternative stoves in Kenya. (See, also, more generally, Bailis et al, 2005.) But these remain, on balance, relatively rare.

In 2004, Bond et al (2004, 23) argued that changes in ‘residential solid fuels have not been considered a major part of a solution to the greenhouse-gas problem because most solid fuels (excluding coal) are considered “renewable”’. In other words, because the harvesting (and growth) of the biomass was often not explicitly considered (Bailis et al, 2003, 2051), but instead was implicitly assumed to be sustainable, this sector was not identified as a climate change mitigation priority. Hence, significant research attention was not devoted to it.

As a result, when the IPCC reviewed the issue, three years later, they concluded that, with respect to residential and commercial buildings, there ‘is a critical lack of literature and data about [greenhouse gas] emissions and mitigation options in developing countries. Whereas the situation is somewhat better in developed regions, in the vast majority of countries detailed end-use data is poorly collected or reported publicly, making analyses and policy recommendations insufficiently robust’ (Levine et al, 2007, 437). Nevertheless, interest in cookstoves as a climate change mitigation option has grown since that time, prompted not least of all by the fact that recent evidence has shown that black carbon is a more significant contributor to climate change than previously thought. With solid fuel use by households in the developing world responsible for 18 per cent of all black carbon emissions (World Bank, 2009, 312), its consequent rise up the agenda is not surprising. (See Legros et al, 2009, 28; and World Bank, 2009, 312, more generally.)

Cookstove replacement can have significant co-impact consequences, with changes to indoor air quality being particularly prominent.[12] More specifically, pollutants produced by the combustion of biomass while cooking and/or heating include – in addition to carbon dioxide – particulate matter, carbon monoxide, nitrogen and sulfur oxides, benzene, formaldehyde, and polycyclic organic matter, including carcinogens such as benzo[a]pyrene (Ezzati and Kammen, 2002, 1057; WHO, 2002, 69). These emissions then lead to increased concentrations of these pollutants inside the home, which, in turn, can have implications for human health.

> Exposure to indoor air pollution (IAP) from the combustion of solid fuels has been implicated, with varying degrees of evidence, as a causal agent of several diseases in developing countries, including acute respiratory infections (ARI) and otitis media (middle ear infection), chronic obstructive pulmonary disease (COPD), lung cancer (from coal smoke), asthma, cancer of the nasopharynx and larynx, tuberculosis,

> perinatal conditions and low birth weight, and diseases of the eye such as cataract and blindness (Ezzati and Kammen, 2002, 1057; see, also, WHO, 2002, 70; and Fullerton et al, 2008).

There exists a rich literature regarding the links between indoor air quality and human health in developing countries. General reviews can be found in Dherani et al (2008), Legros et al (2009, 48), Mehta and Shahpar (2004), Naeher et al (2007), Rehfuess et al (2009) Smith et al (2007), Torres-Duque et al (2008) and World Bank (2010f). The World Health Organisation has quantified the impact:

> Indoor smoke from solid-fuel use contains a range of potentially harmful substances, from carcinogens to small particulate matter, all of which cause damage to the lungs. Indoor smoke from solid fuel causes about 21% of lower respiratory infection deaths worldwide, 35% of chronic obstructive pulmonary deaths and about 3% of lung cancer deaths. Of these deaths, about 64% occur in low-income countries, especially in South-East Asia and Africa. (WHO, 2009, 23)

Indeed, for low income countries, 'indoor smoke from solid fuels' is the sixth highest risk factor causing death (responsible for 1.3 million deaths, 4.8% of all deaths attributable to one of 24 identified risk factors), and the fifth highest risk factor leading cause of disability-adjusted life years (DALYs), responsible for 33 million DALYs (4.0% of total) (WHO, 2009, 11). Focusing more closely upon the poorest within these countries, Malyshev (2009, 40) reports that the

> prevalence of indoor air pollution is significantly higher where income is below a dollar per day per capita. As well as being much more dependent on biomass, poor households rely on low-quality cooking equipment and live in poorly ventilated housing, exacerbating the negative health impact, as there is incomplete combustion and non-dissipation of smoke.

This has encouraged a focus upon more-efficient cookstoves to improve indoor air quality and health.[13]

Turning to Africa's least developed countries, Dionisio et al (2008) measured carbon monoxide and particular matter concentrations in households in The Gambia; the range of values across time and across space within the household was highlighted by the authors. Fullerton et al (2009) measured the same variables in Malawian households, while Kumie et al (2009) focused upon NO_2 concentrations as their indicator of indoor air pollution in selected Ethiopian households. Ellegård (1996) examined the relationship among fuel type (including wood and charcoal), particulate matter concentration and respiratory impacts in Mozambique. And Kilabuko and Nakai (2007) investigated the pathways between, first, biomass fuel use in homes and concentrations of particulate matter, NO_2 and carbon monoxide and, second, these pollutants and respiratory infections. Their case-study was a Tanzanian village.

The links among the three pieces of information needed to investigate fully cookstove replacement as a climate change mitigation option in Africa's least developed countries are relatively thin, though they do exist. In the middle of the last decade, Bond et al (2004) provided one of the first studies to make connections between local and global pollutants arising from residential fuels and Masera et al (2005) highlighted the importance of a 'systemic' approach in understanding all sets of pollutants associated with household energy use in Mexico. More detailed studies – going beyond general statements of importance, and attempting to quantify impacts on different scales – were forthcoming by the end of the same decade. Panwar et al (2009), for example, examine the benefits of reduced pollutants, both local air pollutants and greenhouse gases, arising from use of modified single pot and double pot improved cookstoves in the Himalaya in India, and Venkataraman et al (2010) reflect upon the same, for India as a whole (see, also, Wilkinson et al, 2009).

Turning to our 34 countries under investigation, studies are scarcer. For an individual country investigation, the closest uncovered to the 'ideal' I lay out above is that of Yamamoto et al (2009), who examine the common fuel types used (wood, charcoal and liquid petroleum gas) in terms of consumption, energy, availability, air pollution and climate change for the semi-urban area of Nouna, Burkina Faso. At a regional level, Hutton et al (2007, 42) complete what they argue is the first global cost-benefit analysis of interventions to reduce indoor air pollution – including both 'local' and 'global' air quality improvements. Pulling out results for 'AFR-D' and 'AFR-E', which include, collectively, our countries, we see that the benefits outweigh the costs significantly – 'very good value for money' is a conclusion that they reach (Hutton et al, 2007, 40). Part of the benefits consists of global environmental benefits (including declining greenhouse gas emissions) and reductions in health care costs; 'time savings', however, provide the majority of the savings according to their calculations. Nevertheless, this kind of integrated assessment remains the exception rather than the norm.

2.2 Carbon-free grid electricity

Access to electricity is an important catalyst for development – in discussions of the Millennium Development Goals, this had often been noted, and a variety of studies have revealed the developmental impacts of providing power to communities. Barnes et al (2010, 3), for example, argue that increased electrification bring a range of benefits, including energy services in the evening that extend ‘work and study hours and [contribute] to productivity and educational achievements’. (See, as well, Barnes, 2007; Khanna and Rao, 2009, p. 20.24; and World Bank, 2008.) Given, however, that more than two-thirds of global electricity is provided by means of fossil fuel combustion (IEA, 2010, 24) – with its attendant carbon dioxide and other greenhouse gas emissions – it is not particularly surprising to find that decarbonisation of electricity supply is often identified as a climate change mitigation option.

In this section, I follow the pattern I have established above and seek to determine the state of knowledge with regard to three areas: i) the cost of generating electricity by non-carbon means, as compared to conventional generation; ii) the greenhouse gas emission reductions associated with this change; and iii) the characteristics of a key co-impact arising from the action. Again, while there has been at least some work on each of these individual elements, relatively little has put all of the pieces together.

The costs of renewable means of electricity generation – in particular, wind and solar – have received considerable attention. Reviews include REN21 (2010) and WEC (2010). Indeed, the IPCC’s Third Working Group devoted considerable attention to it in its Fourth Assessment Report (Sims et al, 2007). In our particular countries under investigation, there have been studies of the technical feasibility of expanding use of renewable resources, and the associated costs of doing so (Murray et al, 2010; Azoumah et al, 2011). While information sources are sometimes protected for proprietary purposes (renewable energy developers want to guard assessments of the resource potential, for fear of assisting competitors with their evaluations), the amount of data in the public domain are still noteworthy.

Turning to a consideration of the greenhouse gas emission reduction potential, the calculation of the ‘baseline’ (that is, what would have happened in the absence of this project) is important. In other words, the mitigation potential is different if the new renewable electricity initiative (e.g., a wind farm attached to the national grid or a remote solar-hydropower hybrid system) is displacing an existing or planned coal-fired power plant, a natural gas-fired plant, a diesel generator or something else; additionally, the particular kinds of fossil fuel technology and the efficiency of the same will also be important. Notwithstanding the range of combinations of new (renewable) and old or planned (fossil) technologies possible, much work has been done on the so-called 'emissions factors' associated with various electricity generation technologies (e.g., Sims et al, 2007). Thus, a calculation of the greenhouse gas emission reduction potential is fairly straightforward by comparing and contrasting the 'new' and the 'old or planned'.

In our particular region, it is – unlike other parts of the developing world (for instance, China and India) – not primarily about displacing fossil fuels with renewables. Table 2 reveals that over 80% of the electricity generated in these 34 countries, in 2007, was done so by non-carbon means. Moreover, the reserves of fossil fuels in these countries are modest. At the end of 2009, a category called 'Other Africa' (which included our 34 countries, plus some others) together accounted for 1,103 million tonnes of coal reserves or 0.1% of the global total (BP, 2010, 32); similarly, at the end of 2009, a category with the same label (though some different countries, but still our 34 countries of interest in this article) contained countries having 1.27 trillion cubic metres of natural gas reserves, which represented 0.7% of the global total (BP, 2010, 22). Thus, it may be hard to argue that alternative means of electricity generation will necessarily displace carbon-based alternatives (given how modest they are in any reasonable 'baseline'). Instead, for this strategy to be developed as a climate change mitigation strategy, it requires a different kind of 'framing'.[14]

First, in the countries under consideration in this article, although Table 2 reveals significant amounts of hydropower generation, recognise that fossil-based generation still constitutes almost 20% of the existing generation base. Additionally, some think that the use of diesel generators – which are, of course, greenhouse gas emitters – may be higher than official figures reveal, because of firms' frustration with the interruptability of power supply in some sub-Saharan African countries (Foster and Steinbuks, 2009). And given the extent to which the historically predominant paradigm of 'grid-extension means of electricity supply' has fallen into disrepute, prospects for even greater use of diesel for electricity generation in the future are higher than might otherwise be thought (Sebitosi and Okou, 2010).

Table 2 – Electricity generation, by source, 34 African countries, 2007.

Source	**Generation (billion kWh)**	**Percentage share of total**
Hydropower	50.332	81.9
Conventional thermal	11.047	18.0
Biomass and waste	0.057	0.1
Solar, tide and wave	0.006	0.01
Total net generation	61.443	100.0

Source: EIA (2010)

And second, there is the possibility that carbon-free electricity generation in our countries under investigation can displace fossil fuel use in electricity generation (existing and/or planned) in neighbouring countries. It is important to remember that some African countries use substantial quantities of fossil fuels in their electricity generation. Though not part of our sample of 34 countries, South Africa, Nigeria and the countries of North Africa make substantial use of fossil fuels in their electricity generation and have considerable reserves of fossil fuels. With respect to the former, Table 3 reveals that each of these countries, on its own, has more conventional thermal generation than, collectively, the 34 countries that we are studying have. Indeed, in the case of South Africa, the difference is a factor of more than 20. And, with respect to the latter, with, for instance, Nigeria having 2.8% of the world's natural gas reserves, Libya 3.3% of the world's oil reserves and South Africa 3.7% of the world's coal reserves, there is the potential for substantial continued use of fossil fuels in the future (BP, 2010). Why does this matter to our 34 countries, particularly with respect to a discussion of co-impacts? First, co-impacts of such displacement could be felt in our countries through means of, for example, increased export earnings and improved air quality.[15] And second, co-impacts could accrue to these thermal-generation-intensive countries (e.g., improved air quality), and they might be willing to pay our countries a premium for them. With that context as additional motivation for my analysis, I now turn to a key co-impact.

Table 3 – Electricity generation by conventional thermal means, selected African countries, 2007.

Country	**Thermal generation (billion kWh)**	**Thermal generation, as share of total generation (percentage)**
Algeria	34.752	99.4
Egypt	102.261	86.4
Libya	23.983	100.0
Morocco	19.973	92.7
Nigeria	15.578	71.1
South Africa	226.991	84.5
Tunisia	13.695	99.3

Source: EIA, 2010.

Again following the pattern in the previous section, I focus upon one key co-impact, to illustrate the kind of approach taken[16] -- namely, the consequence for outdoor air quality. In 2009, the World Health Organisation (WHO, 2009, 23) reported that:

> Industries, cars and trucks emit complex mixtures of air pollutants, many of which are harmful to health. Of all of these pollutants, fine particulate matter has the greatest effect on human health. Most fine particulate matter comes from fuel combustion, both from mobile sources such as vehicles and from stationary sources such as power plants.

The causal chain – or pathway – is quite direct: source emissions travel through the atmosphere and are inhaled by individuals; they affect health in both the short-term (premature mortality, hospital admissions) and longer-term (morbidity, lung cancer, cardiovascular and cardiopulmonary diseases, etc) (Valavanidis et al, 2008).

As compared to indoor air pollution, the problem of outdoor air pollution is not as widespread in the countries under examination in this article. For low- and middle-income countries as a whole, urban outdoor air pollution was responsible for 1.9% of all risk factors causing deaths, while indoor smoke from solid fuels was responsible for 3.9% of all risk factors causing deaths; the respective figures for percentage of all DALYs were 0.6% and 2.9% (WHO, 2009, 24). Indeed, if the data were restricted strictly to the countries we are examining, then the spread would be even wider: the WHO (2009, 3) notes that it is indoor air pollution that is classified as a 'traditional risk', while urban air quality is a 'modern risk'. Nevertheless, outdoor air pollution is still a risk for many of the countries we are examining, and, with increasing urbanisation and economic growth, may well be increasing (ECA, 2009, 35).

While the literature to examine the co-impacts of improved outdoor air quality (arising from the decarbonisation of electricity grids) has, at least in the developing world, received only modest coverage to date, there are nevertheless some studies that have been completed. (Anenberg et al, 2010 provide a broad review.) He et al (2010), for example, investigated the impact of a portfolio of energy efficiency and fuel-switching policies in China, finding not only greenhouse gas emission abatement but also a reduction in the emission of local air pollutants, which results in a 12%-32% decline in ambient air pollutant concentration by 2030. Markandya et al (2009), moreover, examined the health impacts arising from reduced use of coal without carbon capture in India – in particular, identifying the mortality impacts arising from the associated reduction in particulate emissions.

Turning to Africa, however, there has been relatively little work linking electricity emissions and human health impacts. Given the paucity of fossil fuel generating stations in many parts of the continent, this is not particularly surprising. Some work has been done in South Africa (e.g., Nweke and Sanders III, 2009), but both the sources of emissions and the impacts of emissions were South Africa-specific; any kinds of interactions with neighbouring countries were not investigated. Thus, a link among the 'ideal' elements identified for our integrated analysis cannot be made.

2.3 Improved industrial efficiency

Improving efficiencies across a range of processes is important to the advancement of any society. 'Doing more with less' is a mantra made famous by the Business Council on Sustainable Development (BCSD) as it encouraged industries to reduce input demands and to lower waste production (Schmidheiny, 1992). Of course, this advice predates the 1990s' work of the BCSD, and, in energy applications, the importance of efficiency gained initial prominence in light of the oil crises of the 1970s and 1980s (Lovins, 1976). With so many energy services, world-wide, being provided by fossil fuels,[17] it should come as little surprise that 'energy efficiency' is often advanced a key climate change mitigation strategy. Therefore, following my approach in the previous two sub-sections, I review three strands of information that would be critical in an 'ideal' evaluation of the co-impacts of energy efficiency as a climate change mitigation option – namely, i) the cost of energy efficiency strategies; ii) the climate change consequences of energy efficiency strategies; and iii) a key co-impact of the same. The focus in this section is upon the industrial sector, though many of the messages apply to other sectors in which energy is used (including transportation and agriculture).

The literature on eco-efficiency, within which there is a significant emphasis on energy efficiency, highlights the 'win-wins' that can be generated by the process changes (e.g., new technologies, new management systems) that serve to minimise resource inputs and waste outputs (DeSimone and Popoff, 1997). The literature highlights the fact that these are 'wins' not only in terms of environmental goals, but also in terms of financial returns. Indeed, phrases like 'low-hanging fruit' and 'ten-dollar bills' are often used in the literature on industrial energy efficiency, revealing means by which process changes can improve business performance (e.g., Shipley and Elliott, 2006).

Others, however, challenge this position, for they maintain that there are specific costs associated with bringing in new approaches (Walley and Whitehead, 1994) or that the opportunity costs of such action may be high – diverting, that is, attention away from other, more-lucrative areas for innovation (Cairncross, 1991). Additionally, there may well be increased risk, increased training requirements, and production losses during the transition to the new ways of doing things (the capital transformation required, for instance) (Bernstein et al, 2007, 485). Finally, one has to ensure that the energy efficiency activity does not, inadvertently, displace the environmental impacts to other parts of the product chain (for example, the energy required to make the new machinery that is, in turn, needed to make the energy-efficient technology; or, from the renewable energy field, the 'energy payback time' to produce the renewable energy generator) (Perpiñan et al, 2009). The debate about the merits of energy efficiency – and the extent to which 'win-wins' actually exists – continues (e.g., Ambec 2008).

Turning to climate change, many highlight the attractiveness of energy efficiency strategies. Examining the prospects across different industrial sub-sectors around the world, Worrell et al (2009, 26) are extremely bullish on the contribution that can be made: 'Although industry has almost continuously improved its energy efficiency over the past decades, energy efficiency remains the most cost-effective option for [greenhouse gas] mitigation for the next decades.' Prospects in developing countries may be particularly bright, for this is 'where old, inefficient technologies have continued to be used to meet growing material demands' (McKane et al, 2008, 3).

In this sub-section, I again focus upon one particular co-impact, while still recognising that there is a wide range of co-impacts arising from increased industrial energy efficiency.[18] The one selected is the impact upon employment – an area in which there is an emerging literature, as well as great political interest.

On the one hand, many argue that energy efficiency – focusing more upon labour capital instead of resource capital – has the potential to increase jobs. (And there are other mechanisms/pathways as well – new market opportunities arising from exploting a first-mover advantage; improved competitiveness through lower operating costs; spillover effects may mean that there is more money available to stimulate other parts of the economy.) A representative quotation comes from a UNEP report (completed, on its behalf, by the Worldwatch Institute): 'Macroeconomic studies, most of which have occurred in the United States and European Union, show that these energy-efficiency measures lead to an overall net increase in jobs' (UNEP, 2008a; see, also, Barbier, 2010). The most recent IPCC assessment is sprinkled with assertions of how mitigation can lead to net increases in jobs – for example, in the chapter on 'residential and commercial buildings', 'Most studies agree that energy-efficiency investments will have positive effects on employment, directly by creating new business opportunities and indirectly through the economic multiplier effects of spending the money saved on energy costs in other ways.' (Levine et al, 2007, 417), and in the chapter on 'energy supply', 'Increased net employment and trade of technologies and services are useful co-benefits given high unemployment in many countries. Employment is created at different levels, from research and manufacturing to distribution, installation and maintenance' (Sims et al, 2007, 310). Developing countries may be particularly well-positioned to reap these benefits, for they 'are often characterised by large reserves of unemployed or under-employed persons in the informal sector[; therefore,] there will be relatively more scope for green growth initiatives to raise overall productive employment' (OECD, 2010, 54-55).

While it is broadly accepted, at least in the short-term, that these strategies will generate jobs – the evidence arising from the implementation of various stimulus packages around the world is serving to support this – there are a number of questions that are raised about the persistence of such jobs. Some economists argue that learning and associated efficiency gains (as well as economies of scale) will make the permanency of these jobs more tenuous. Moreover, those studies that do exist – and important for my purposes is that relatively few have been completed in the developing world (Levine et al, 2007, 6.6.4) – are often done by industry proponents, and only look at the jobs generated on a project-by-project basis; the 'net' impact on employment, which would also consider those sectors that contract in the face of climate change mitigation activities, are not usually examined. The OECD is investigating further this issue, and examining it in depth in its forthcoming 2011 Synthesis Report.

We now turn to the 34 countries in Africa that are under particular investigation in this article. Interest in energy efficiency in industry is, in general, relatively low across these countries. This follows, of course, from the fact that the level of industrialisation in these countries is relatively low. For more than two-thirds of these countries, industry's value-added, as a percentage share of GDP, is less than 25%. The exceptions are the following resource-rich countries: Equatorial Guinea (95.7%), Angola (67.8%), Chad (48.8%), Mauritania (46.7%), Guinea (46.4%), Zambia (46.3%), Lesotho (34.8%), Sudan (34.1%), Democratic Republic of the Congo (28.0%) and Uganda (25.8%).[19]

But turning to the perceived level of interest in industrial energy efficiency, consider the following examples. First, note that National Cleaner Production Centres (supported by UNEP/UNIDO) have been established in 40 countries worldwide. Of the ten in Africa, however, only three can be found in the countries in our sample (Ethiopia, Mozambique and Uganda (ECA, 2009, 83)). Thus, while our sample accounts for almost two-thirds of the countries across the continent, it only has less than one-third of the countries with such centres. Second, it is broadly accepted that efforts to advance clean production in Africa as a whole have made only limited inroads. These Centres, for example, have done well to raise awareness, but the issue of energy efficiency continues to be absent from the agenda of financing institutions, industry associations and government industry departments across the continent (ECA, 2009, 85). Indeed, of the almost 200,000 ISO 14001 certificates present worldwide, only 55 (0.03 per cent) are found in our 34 countries. And third, data in Africa are hard to come by, thus making it difficult to make any recommendations to improve energy efficiency in industry:

> There is a lack of reliable data on pollution and resources use, industrial emissions, or environmental impacts of consumption and these constitute major obstacles to the development of targeted and effective policies and goals. There is a also lack of relevant [sustainable consumption and production] indicators in national statistics. The importance of having good indicators cannot be overstated. What is not measured will be ignored. Few research are being carried out at national level on consumption and production patterns. (ECA, 2009, 107)

All of this leads some to believe that energy efficiency may play only a modest future in the continent – as a climate change mitigation option, it does not get much of a mention in the McKinsey & Company (2009, 72) report, with others areas' potential being highlighted more. Moreover, given that only three of our 34 countries draw 'a significant part of their export revenues from manufactured products' – Angola, Madagascar and Zambia – there does not seem to be much potential motivated by foreign stakeholders (ECA, 2009, 17). However, the growth in number of countries with at least one ISO 14000 certificate – from eight of our 34 in 2005 to 16 in 2008 – hints, potentially, at emerging interest in this area. Regardless, it is certainly the case that the situation in the countries under investigation in this article follow the more general trend, identified by Liverani (2009, 8), that the 'estimation of costs and benefits of energy-efficiency projects often do not include nonenergy co-benefits'. Thus, this area would appear ripe for further investigation; a rationale for encouraging such further study is presented in the next section of this paper.

3. Research needs

What this review of the selected co-impacts of three energy-related climate change mitigation strategies in Africa's least developed countries has revealed is that there is information available to construct – or at least to serve as a starting point for the construction of – a sophisticated integrated analysis. However, investigations into the co-impacts of greenhouse gas emission reductions for Africa's least developed countries are relatively rare. In other words, many of the building blocks are often there, but the builders to put them together have yet to arrive and to take action. Let me elaborate by briefly reviewing each of my three areas of investigation.

Table 4 – Evidence base for selected co-impacts of three energy-related climate change mitigation strategies in Africa's least developed countries

Energy-related climate change mitigation strategy	**Selected co-impact**	**Evidence base for mitigation strategy (cost and environmental impact), generally**	**Evidence base for co-impact**	**Evidence base for mitigation strategy in Africa**	**Evidence base for co-impact in Africa**	**Linkage between mitigation strategy and co-impact**
more efficient cookstoves	better indoor air quality	medium	medium-high	medium	low-medium	low-medium
carbon-free electricity	better outdoor air quality	high	low-medium	medium	low	low
improved industrial energy efficiency	job creation	medium	low-medium	low	low	low

Table 4 summarises the results from section 2 of this article. The third and fourth columns evaluate the strength of the evidence base, generally, with regard to a couple of the 'individual parts' of those key analyses that I described earlier. The fifth and sixth columns, meanwhile, report upon the same with respect to our African countries under investigation. Finally, the last column reveals the extent to which these elements have been put together. In tabular form, this Table arrives at the same conclusion as presented in the previous paragraph – namely, there are some elements present, but the integration is largely missing. More specifically, the strategy of deploying more efficient cookstoves would appear to be the candidate that is ripest for such analysis, with relatively good evidence bases in place. By contrast, the evidence bases for carbon-free electricity and improved industrial energy efficiency not only have few linkages among component parts, but the understanding with respect to the co-impact itself is relatively low.

Of course, my conclusion that, notwithstanding the calls for such an investigation that I highlighted in the first section of this article, this kind of integrated assessment is not present is not particularly novel. The Fourth Assessment Report of the IPCC identified, across a number of the chapters in the work of the Mitigation Working Group, the need for more research in this area. In the chapter on 'residential and commercial buildings', it is argued: 'In existing assessments of mitigation options, co-benefits are typically not included, and in general, there is an important need to quantify and monetize these so that they can be integrated into policy decision frameworks.' (Levine et al, 2007, 437) And in the chapter on 'industry', one of the few 'key gaps' in knowledge identified was 'co-benefits, [sustainable development] implications of mitigation options' (Bernstein et al, 2007, 488). These snippets are consistent with Sathaye et al's subsequent analysis (2010) that 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")'. Since 2007, that sentiment has been echoed by many. Labriet et al (2009, 156-57), for instance, maintain that there is a need for 'better quantification and accountability of the sustainability aspects and co-benefits beyond [greenhouse gas] reductions (other air pollutant reductions, other environmental impacts reduction as well as other socio-economic co-benefits of the project)'. More generally, it has been noted that 'little evaluation has been conducted ... regarding the efficiency of outcomes and co-benefits or the social costs generated by carbon-mitigation projects' (Wittman and Caron, 2009, 710).[20] Calls from within Africa are present as well. One researcher argues that '[f]urther research will have to provide more insight into how to frame more robust strategies at the local, national and regional levels that will address Africa's development-climate goals, taking cognizance of the peculiar circumstances and challenges of the continent' (Chuku, 2010, 51).

As suggested in the first section of this article, there has been increased effort to address this gap.[21] The Asian Development Bank, for instance, has supported the development of a 'Co-Benefits Network' through its Clean Air Initiative for Asian Cities (CAI-Asia Centre, 2009). The UNEP has co-benefits as an important part of its climate change strategy for 2010/2011 (UNEP, 2008b). And the World Bank has this as a theme throughout much of its recent work – for example, the World Development Report 2010, the Environment Strategy 2010 and the activities of the Clean Technology Fund (Nishimae, 2010). The broader trend of integrating themes across climate analyses – not least of all a new effort to consider, concurrently, mitigation and adaptation issues – would seem to suggest that broader trends will serve to support such sentiments and ambitions.

But while this work is emerging, the trend seems to be that it is focusing upon parts of the developing world that are outside of the countries under investigation in this article. Consider the first of my mitigation strategies. Of the 21 studies that the IPCC reviewed that had considered ‘air quality co-benefits from greenhouse gas mitigation studies’ (Barker et al, 2007, 671-72), for example, six focused upon China, four upon Latin America (primarily Mexico), two upon Korea, one on Thailand and one on India. More recently, Pittel and Rübbelke’s 2008 review of studies regarding the ‘ancillary benefits’ (they focus upon pollutants) in ‘developing and transformation countries’ found two from transition economies (Hungary and the Russian Federation), seven from China, two from Chile and one from India. Bell et al (2008) aim to ‘illuminate the weight of evidence’ with respect to ‘ancillary benefits in terms of short-term improvements in air quality and associated health benefits’. They identify 14 key studies, with seven being in the developing world (four in Latin America and three in China). Meanwhile, in Bollen et al’s 2009 review of nine such studies (which again, notwithstanding a title of ‘co-benefits’, nevertheless focuses upon ‘local air pollution co-benefits’), four have a global focus, while three look at individual developing countries: China, India and Vietnam. Then Nemet et al’s 2010 study of ‘studies estimating the [air quality] co-benefits of climate change mitigation in developing countries’ found seven in China, four in Latin America (predominantly Mexico), and one each in India and Thailand. Instructive in this brief review of these meta-surveys is that not one had a study that focused upon one of our 34 countries under investigation.

Thus, a priority for the research communities concerned with improved cookstoves as a climate mitigation and development strategy would appear to be an integration of efforts. More specifically, I call for a bringing-together of the climate change research community and the air quality research community, with respect to the least-developed countries in Africa. While attention is also needed upon the other two strategies I examine in this article, a focus of this kind upon indoor air quality is appropriate for at least four reasons.

First, this is an issue that has the potential to affect many of the world’s poorest people. Second, there are a range of climate change mitigation-related strategies that can serve to improve indoor air quality in Africa’s poorest countries – this can be improved stoves (as examined in section 2.1 of this article), fuel substitution (for example, kerosene in place of biomass) and electrification (through either grid extension or mini-grid development). As such, it opens the door to investigation of a range of mitigation activities. Third, while I focus upon ‘air quality consequences’ – suggesting that that is the primary co-impact to be examined – the investigation I propose here would also serve to open the door to other areas. As but one example, as noted in the investigation on improved industrial energy efficiency above, studies on employment impacts have often yielded ambiguous results, or had nontransparent methods; work on this issue with respect to improved cookstoves would serve to 'raise the bar' with respect to the quality of research being completed. Hence, there would be important research 'spillover' effects. And fourth, though this is an 'energy-related mitigation strategy', its links with land-use issues – the other key mitigation area for Africa's poorest countries, as noted in the first section of this article – is evident, and thus would allow reflection (and potential interaction with) this other agenda. Consequently, this initial proposal has a clear focus (cooking/heating strategies), but various tentacles that would acknowledge the interconnections that exist in such issues, and potentially identify other priorities.

That having been said, there are also opportunities to advance research on the other two issues investigated in this article. In some ways, however, more fundamental steps need to be taken – namely, the evidence base regarding the specific mitigation strategy and, in particular, the co-impacts need to be improved in the case of Africa's least developed countries.[22] After that has occurred (or perhaps in parallel with that effort), integration of these elements could be made. Such cross-fertilisation of information and ideas would serve to benefit both the energy and the climate agendas (cf Bazilian et al, 2010, more broadly).

4. Summary and conclusions

The purpose of this article has been to investigate a key co-impact arising from each of three energy-related climate change mitigation strategies in Africa's least developed countries. The specific cases investigated were: the indoor air quality improvements arising from deployment of improved cookstoves; the outdoor air quality improvements following from use of carbon-free electricity; and the job creation consequences resulting from increased industrial energy efficiency. These three cases were selected because of their significance (current and/or potential). Moreover, they were meant to be at least partially illustrative – showing the kinds of evidence that could be gathered and thus the 'case' to policy-makers and communities more broadly that could be made.

The investigation revealed that while links between climate change analyses and co-impact (local) analyses have yet to be made comprehensively – particularly in an African context – the strongest evidence base for the constituent parts exists in the case of the strategy of improved cookstoves. Consequently, I recommend that the climate change and air quality research communities integrate their findings so that a more informed decision can be made by policy-makers and so that support for a development-consistent climate policy can be advanced. I further recommend that further work on the details of the other two strategies as a climate change mitigation strategy, as well as the co-impacts of the same, be advanced, so that a comprehensive plan can be developed.

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Endnotes

[1] The focus of this paper is those 34 countries of Africa that are identified by the United Nations as 'least developed'. There are 49 such countries in total, globally (UN, 2010).

[2] Calculations use data provided in Federal Democratic Republic of Ethiopia (2001). Global warming potentials for methane and nitrous oxide are taken as 21 and 310, respectively (100 year values, IPCC (1995, 22)).

[3] Rankings are based upon 2008 population figures taken from World Bank (2010a).

[4] Calculations use data for 2005 taken from World Bank (2010b, 2010c, 2010d, 2010e, 2010a). Using the same sources of data for Ethiopia, a figure of 1.56 tonnes CO2e/capita results for that country.

[5] Some funders consider multiple criteria. Those developing 'gold standard' emission reduction credits, for example, investigate the broader social and environmental impacts of mitigation projects (Kollmuss et al, 2010, Chapter 7), but they remain in the minority.

[6] Barker et al (2007, 662) identify a number of investments, made today, that have 'staying power' for more than 60 years: glass manufacturing, cement manufacturing, steel manufacturing, metals-based durables, roads, urban infrastructure and some buildings; many other kinds of capital stock have lifetimes that extend between 30 and 60 years (see, also, Stern, 2007, 232). Indeed, communities live with the consequences of urban planning decisions for decades (Cosbey, 2009, 31). See, as well, Unrah (2000) on the general concept of carbon lock-in.

[7] Remember, as well, that when mitigation attention is focused upon the developing world, it is not only about the present portfolio of emissions, but also the trajectory projected into the future – the so-called baseline. As such, there is interest in not only what is 'on the ground' now, but also what is contained in the plans for the future.

[8] Twenty-three countries have submitted one National Communication; six have submitted two (Burundi, Democratic Republic of Congo, Madagascar, Mauritania, Niger and Senegal); and five have not submitted any (Angola, Equatorial Guinea, Liberia, Somalia and Timor-Leste). As of 1 December 2010 from UNFCCC (2010b).

[9] As of 1 December 2010 (UNFCCC, 2010b): Benin, Central African Republic, Chad, Ethiopia, Eritrea, Madagascar, Mauritania, Sierra Leone and Togo.

[10] Of course, other sectors – for instance, waste management – also have co-impacts associated with them (e.g., Zusman, 2008, 88). They, too, warrant attention.

[11] Again, space restrictions preclude an exhaustive study. Transportation energy-related mitigation options (e.g., fuel efficiency standards and increased use of mass transportation) are but a series of possibilities that are not pursued in this article (cf, for instance, Machado-Filho, 2009).

[12] While this article focuses upon one key co-impact associated with each of three energy-related climate change mitigation options, the reader is encouraged to consider other co-impacts. Regarding the deployment of more efficient cookstoves, other co-impacts include the consequences for women and children's well-being (apart from air quality-related health benefits), shifts in employment and changes in educational opportunities (e.g., Hutton et al, 2007, 42; Malyshev, 2009, 41; Mehta and Shahpar, 2004, 58; Schirnding et al, 2002, 24; Yamamoto et al, 2009).

[13] A contradictory position is provided by Sathaye et al (2010), who argue that 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'. These 'other studies', however, are not referenced. Additionally, Sathaye et al (2010, Table 1) note that the 'indoor air pollution and health impacts of improving biomass cook stove thermal efficiency in developing country rural areas are uncertain.' There was no supporting reference provided, however.

[14] Of course, development of renewable electricity capacity could serve to displace non-electrical means of providing energy services – for example, the use of fuels like kerosene, charcoal or other forms of biomass. This would serve to lead to a different range of co-impacts, including some that were reviewed in section 2.1 of this article. (See, as well, Ellis et al, 2009, 55.) My focus in this section – for the sake of illustration – is the strategy to displace either carbon-intensive electricity or plans for carbon-intensive electricity with carbon-free electricity.

[15] With respect to the latter, note that the prevailing winds in all of these thermal-generation-intensive countries mean that emissions from their power plants can eventually end up in other African countries (the northeasterlies in the northern part of the continent expose central and western Africa to such an impact, and the southeasterlies in the southern part of the continent expose their southern African neighbours to the same), carrying pollutants with them.

[16] Other co-impacts that exist include consequences for employment and balance of payments (e.g., Hajat et al, 2009; Jochem and Madlener, 2003; Sarkar and Singh, 2010; Sathaye et al, 2010; and Singh, 2009).

[17] In 2008, more than 80% of primary energy supply, worldwide, came from coal/peat, oil or gas (IEA, 2010).

[18] These include improved productivity, new business opportunities and better relations with stakeholders (e.g., Bernstein et al, 2007, 484; Sathaye et al, 2010; Esty and Winston, 2006; Porter, 1991; Porter and van der Linde, 1995). For assessments on their effectiveness, see Wagner, 2003; and for an application in the developing world, see Murty and Kumar, 2003.

[19] Data from the World Bank are for 2008, with the exception of Mauritania (2007).

[20] Such calls extend beyond traditional 'environmental' areas. In its 2009 Trade and Development Report, UNCTAD noted that, 'The possible linkages or trade-offs between developing-country policies for climate change mitigation and policies geared towards their development and poverty reduction objectives are therefore of central importance for their development path' (UNCTAD, 2009, 134).

[21] Sathaye et al (2010) argue that, 'Recent literature has focused more broadly on treating climate change mitigation as an integral element of development policies ("development first").'

[22] In many instances in this article, I refer to the 34 countries identified as Africa's least developed collectively. I do this simply as a short-hand. I fully acknowledge that while this group is defined by it similar developmental characteristics (at least on one level), it is nevertheless extremely diverse. Hence, Chuku's recent observation, which echoes sentiments in this article, is worth repeating, for it is a reminder of the importance of spatially-specific analyses: 'Given the wide divergence of socio-economic systems and the peculiar challenges faced by individual countries in the continent, further research is required on robust country-specific strategies for pursuing an integrated development-climate policy framework' (Chuku, 2010, 41).