A global clean cooking fuel initiative

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This article calls for engaging the public and private sectors of developing and industrialized countries in a global clean cooking fuel initiative (GCCFI) to bring about a worldwide shift to clean fluid fuels for cooking and heating in 10-15 years' time – with an emphasis on providing clean fuel to the poorest households. This initiative is crucial to implementation of the Millennium Development Goals and the Plan of Implementation of the World Summit on Sustainable Development. The article builds on (1) analyses in this special issue of* Energy for Sustainable Development *of challenges to sustainable development posed by use of solid fuels for cooking and water heating (and for space heating in temperate climates) and opportunities for addressing them by bringing about a shift to clean fluid fuels, and (2) an extensive and compelling literature on the problems posed by this reliance on solid fuels.

1. Introduction

Before discussing issues relating to the formulation and implementation of a global clean cooking fuel initiative (GCCFI), a brief review of the major motivating factors is presented. No attempt is made to provide a comprehensive review of the motivating literature – which would be beyond the scope of this "manifesto". Although several seminal overview publications are alluded to, most references are to other articles in this special *Energy for Sustainable Development* issue (which offer a more scholarly approach to this literature).

Studies have shown that human welfare, as measured by the Human Development Index (HDI), increases with diminishing returns as the level of modern energy services provided increases[1]. The HDI increase is especially large for provision of the first increments of modern energy carriers to satisfy basic needs such as cooking and heating, for which demand is very inelastic (cooking and boiling water are essential for survival).

There is wide recognition of the importance of electricity in development and the fact that 1.6 billion people do not have access even to the minimal amounts of electricity required to satisfy basic needs. However, until very recently (see Section 2.2., "Timeliness", below), few policymakers have been aware that the persistent use of solid fuels for cooking and heating is a major impediment to realization of a decent living for some 2.6 billion people.

The amount of clean cooking fuel required to displace these solid fuel is modest – estimated to be about 35 kg of liquid petroleum gas (LPG)-equivalent per capita per year or 50 watts (W) per capita[2] – tiny compared to the commercial energy consumed at the rate of 7500 W by the average citizen of the industrialized world for all purposes[3]. Yet the benefits would be huge – as can be appreciated by considering potential impacts on women, on children, and on public health.

1.1. Empowerment of women

More than 1 billion of the world's females (women and their daughters) whose poor families must rely on "free" solid fuels (fuelwood and dung) for cooking and heating have no hope of rising out of poverty as long as this solid fuel dependence persists. The women in these families, assisted by their children, spend arduous hours every day gathering fuel – e.g., trekking ever longer distances to find and carry back heavy loads of increasingly scarce firewood – and using it to prepare meals using crude stoves, the inefficiency of which aggravates the fuel-gathering task[4].

The fuel used by these households is actually not "free" but rather is non-monetized, because no value is assigned to the labor of the women and children who gather it. If this labor were properly valued and if the health damage costs of solid fuel use were also internalized (see Section 1.3, "Reduced health damage from indoor air pollution", below), solid fuel would be seen as far more expensive

Table 1. Global mortality statistics for the major environmental risks

Environmental risk	Premature deaths (10^6 per year)			Years of life lost (10^6 per year)		
	Male	Female	Total	Male	Female	Total
Unsafe water, sanitation, hygiene	0.90	0.84	1.73	24.9	24.3	49.2
Indoor air pollution	0.66	0.96	1.62	17.3	17.8	35.1
Urban air pollution	0.41	0.39	0.80	3.5	2.9	6.4
Lead exposure	0.16	0.08	0.23	1.9	0.9	2.8
Climate change	0.08	0.08	0.15	2.4	2.5	4.9

Source: WHO, 2002.

Box 1. Public health benefits of shifting to clean cooking fuels

A compelling reason for shifting to clean cooking fuels is to eliminate the health damage caused by indoor air pollution associated with use of biomass and coal for cooking, water heating, and space heating[12]. The World Health Organization has identified indoor air pollution as a global environmental risk causing some 1.6 million premature deaths per year worldwide; an average life-shortening of more than 20 years is associated with these premature deaths, and the overall mortality risk is about 50 % higher for women (who do most of the cooking) than for men (see Table 1). These premature deaths are mostly a result of lower respiratory infections (LRI) in young children and chronic obstructive pulmonary disease (COPD) in adults over age 20. Children exposed to indoor air pollution from household solid fuel use have a 2.3-fold higher risk of LRI, while women exposed to such indoor air pollution have a 3.2-fold higher risk of COPD[13].

Estimating the economic value of such health damage can be helpful in appreciating the urgency of addressing the indoor air pollution risk, but the process is fraught with both scientific uncertainty and uncertainties inherent in the valuation of human health and life itself. Moreover, little has been done to make such valuations. But the work that has been done suggests that human health considerations alone are adequate to justify a shift from solid to clean fluid cooking fuels. Consider, for example, findings of the World Bank report *Clear Water, Blue Skies* on health damage associated with indoor air pollution in rural China[14]. That study estimated that in 1995 the cost of health damage associated with exposure of 109 million people in rural China to indoor air pollution from using biomass and coal for cooking, water heating, and space heating was $ 10.6 billion ($ 98 per capita for those affected) on the basis of the willingness to pay to avoid health damage – the method for health damage cost valuation preferred by most economists. For comparison, our estimate of the delivered cost for imported LPG is about $ 20 per capita per year for typical rural areas in China (based on consumption at a rate of 35 kg per capita per year and LPG costing $ 500-550/t delivered to typical rural areas). The health damage cost would be greater than the fuel cost even using the more conservative human capital valuation of health damage costs in rural China in 1995 according to the above-cited World Bank study: $ 3.7 billion or $ 34 per capita.

than modern clean cooking fuels.

Without external help, there is little prospect that women will be freed of this burden and given the opportunity to become income-earners (e.g., as women entrepreneurs, "womentrepreneurs") to help lift their families out of poverty – because clean cooking fuels are seen as benefiting primarily women. To the extent that a poor household will have any discretionary income at all, it will be spent instead on what will typically benefit primarily the man in the house, who controls the purse. The subordinate role of women extends far beyond the walls of the houses of the poor – all the way to the chambers of political power throughout much of the developing world, where the voices of women are seldom heard.

1.2. Enhanced schooling opportunities for children

It is universally recognized that formal education is key to poverty eradication, but family obligations to gather fuelwood or dung in poor rural households often keep children from school[5]. Thus, making small amounts of clean fuel available is a highly leveraged mechanism for relieving poverty.

1.3. Reduced health damage from indoor air pollution

Over the last 10 years there have been enormous advances in understanding human health damage from air pollution – especially chronic mortality associated with small particle ($PM_{2.5}$)[6] air pollution. An under-appreciated finding of this research is that the most serious health problems are caused by indoor air pollution associated with the burning of biomass and coal in residences[7]. Indoor air pollution causes 5-6 times as much life-shortening as the more familiar urban air pollution and, among major environmental risks, is second only to unsafe water, sanitation, and hygiene as a cause of premature mortality (Table 1). A shift to clean cooking fuels would virtually eliminate this serious public health risk, the cost of which would probably be considerably less than the resulting public health benefits, making this perhaps the most important reason single for bringing about, as rapidly as possible, a shift to clean fuel for cooking and heating (Box 1).

One of the articles[8] in this special *Energy for Sustainable*

Development issue argues that perhaps three-fourths of the health benefit that would arise from shifting to clean fuels could be accomplished in the near term by fitting stoves that burn solid fuels with flues, at a fraction of the cost of shifting to clean fuels. So doing should be considered as an element in a GCCFI as a way to speed up reduction of the health damage that arises from indoor air pollution, but implementing such measures, which are only a partial solution to the health issue and make no significant contribution to addressing the women/children issues posed by the use of solid fuels, should not be a substitute for an accelerated shift to clean fluid fuels.

1.4. Reduced GHG emissions

A final reason for shifting to clean cooking fuels is that, as shown in articles in this special Energy for Sustainable Development issue and elsewhere[9], most clean cooking fuel options (even those based on use of fossil fuels) contribute less to global warming as a result of fuel cycle-wide greenhouse gas emissions as well as black carbon (although there is much scientific uncertainty about the latter) than cooking with coal or biomass.

Even if such climate mitigation opportunities did not exist, climate should not be considered as a factor to discriminate against clean fossil fuel use for cooking and heating, because the total emissions associated with filling this critical development need would be modest – of the order of 1 % of total global emissions of CO_2 from fossil fuel-burning[10].

2. Toward a GCCFI

This article calls for engaging the public and private sectors of developing and industrialized countries in a GCCFI to bring about a worldwide shift to clean fluid fuels for cooking and heating in 10-15 years time – with an emphasis on providing clean fuels to the poorest households. The GCCFI would be an ambitious undertaking because some 2.6 billion of the 4.9 billion people living in developing countries used solid fuels for cooking, water heating, and space heating in 2000[11]. The GCCFI would aim to accelerate the natural ascension with rising incomes up the "energy ladder", to cleaner, more convenient fuels that can be used with greater efficiency:

dung/crop residues → fuelwood → charcoal → kerosene → LPG/natural gas/electricity

and to make clean cooking fuels (CCFs) at the highest rungs on the ladder the norm for even the poorest households.

In what follows the feasibility of, timeliness of, and policy issues relating to a GCCFI are discussed.

2.1. Feasibility

Although problems posed by solid fuel use for cooking and heating by 2.6 billion people are daunting, the solution of shifting to clean fuels over 10-15 years is a global goal within reach. The Brazilian LPG example[15] discussed in this special *Energy for Sustainable Development* issue is an existence proof that with appropriate public policies clean cooking fuels can be brought into use by most of the population in a relatively short period of time. And, there are various reasons to be optimistic that as much or more can be accomplished worldwide.

Consider first that, as noted in the Introduction, the total amount of clean energy required is modest – some 4 EJ per year at the global level, equivalent to about 3 % and 2 % of developing country and industrialized country energy use rates, respectively.

Are there adequate clean fuel supplies to meet this need? At present the energy carrier of choice, where it is available and affordable, is LPG – produced at a global rate of about 200 million tonnes (Mt) per year (about half is used in residences) as a minor by-product of operations at both oil refineries (40 % of total LPG) and natural gas-processing plants (60 % of the total) – accounting in each instance for about 4 % of the primary energy resource processed. Although LPG will certainly be the leading option for meeting these cooking fuel needs in the early years of the GCCFI, meeting with LPG all clean cooking fuel needs of those currently using solid fuels would increase global LPG demand 45 %, and LPG supplies may not be adequate to satisfy all of this demand[16]. However, it is not necessary to rely exclusively on LPG because there are also promising alternatives: although there is no "silver bullet" for attacking the solid cooking fuel problem, there are lots of "lead bullets".

Consider first well-established technologies. Natural gas will come to play ever greater roles in light of the expectation of a rapidly growing world trade in liquefied natural gas (LNG) and an expanded network of transnational natural gas pipelines. During the 10-15 year duration of the GCCFI, some of these natural gas supplies can be directed to urban residences, displacing coal and commercial fuelwood supplies now used in these markets, while freeing up some LPG for use in rural markets. Another urban option is town gas[17], which serves about 43 million people in China today[18]. Biogas, a renewable energy option based on use of local resources, is an important option for some rural areas – e.g., serving more than 20 million people via household-scale biogas systems in China[19]; however, the biogas option is constrained by the availability of appropriate feedstocks (e.g., dung) near users.[20]

In addition to these familiar technologies, dimethyl ether (DME)[21] and ethanol or ethanol gel[22] are new options that offer the potential for providing very large quantities of clean cooking fuels for serving both rural and urban markets – in some instances at costs lower than LPG prices. Ethanol derived from sugar cane in Brazil, for example, is already fully cost-competitive as an alternative to gasoline in transportation (Figure 1) and is likely to be cost-competitive as a clean cooking fuel as well[23]. And, recent analyses suggest that coal-derived DME would be competitive with imported LPG in China[24].

A key consideration regarding the proposed GCCFI is that the goal cannot be realized without providing subsidies to the very poorest households that cannot on their own afford clean fuels such as LPG until incomes rise sufficiently. How much subsidy is justified and who will pay are issues that will be hotly debated and ultimately resolved in different ways in different regions. At the onset of these debates, however, it is crucial to understand that the costs involved are modest – a fact that provides the basis for much of our optimism that the GCCFI is a practically

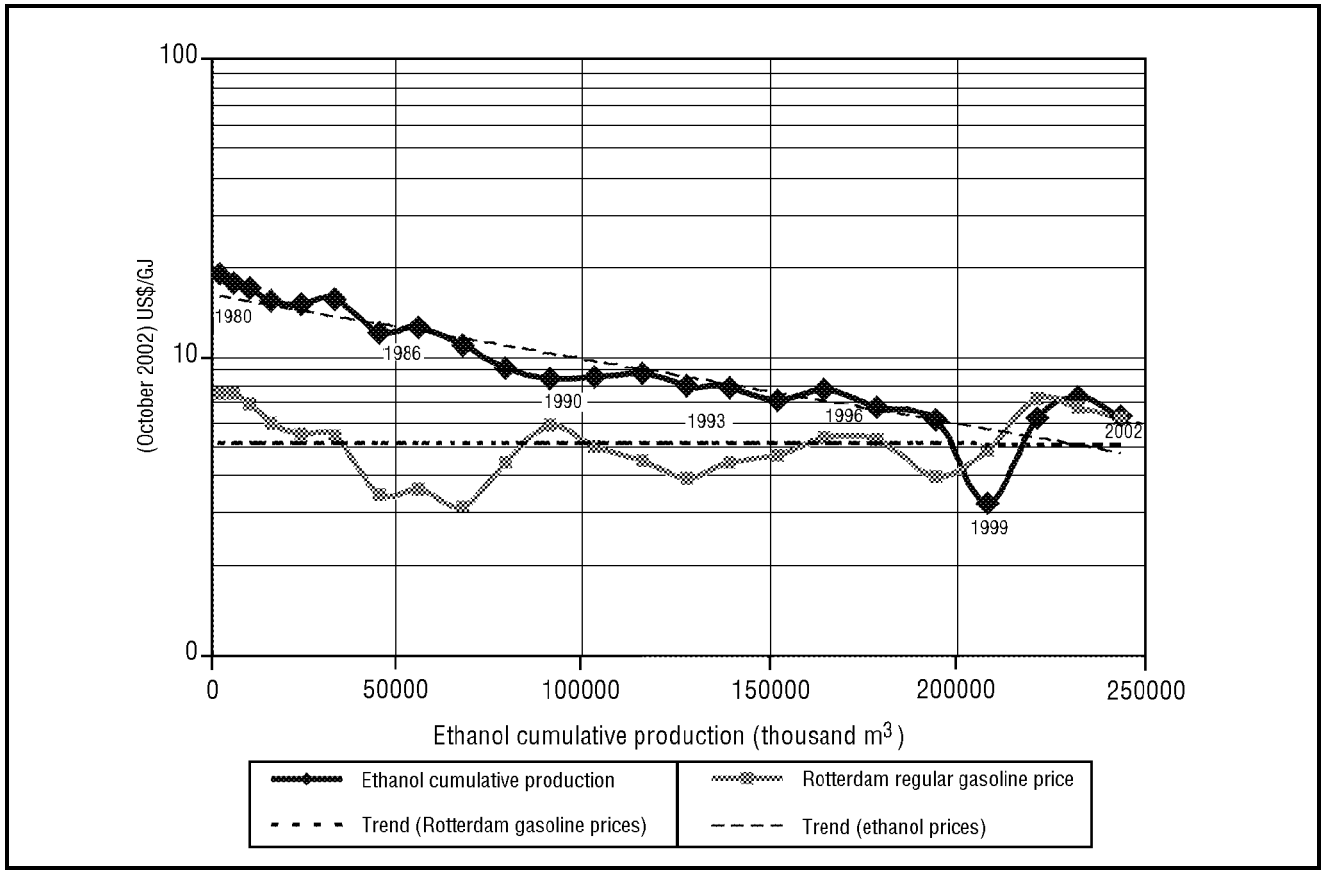

Figure 1. Trend in ethanol prices in Brazil

Source: Goldemberg et al., 2004.

realizable program, even at a persistent $30-a-barrel world oil price. A crude estimate is that the total global cost for clean fuels at the retail level is about $ 50 billion per year[25] – equivalent to 0.8 % and 0.2 % of GDP for developing and industrialized countries, respectively, much smaller than the energy percentages involved. Part of this cost would be borne by consumers, once given access to clean fuels, but subsidies for the poorest households would also be required – provided in part by the governments of these countries and in part by the international community.

2.2. Timeliness

The debates on environment and development have evolved to the point where the global community of policy-makers should be receptive to a GCCFI[26].

A GCCFI would contribute significantly to all[27] of the Millennium Development Goals (MDGs) adopted at the Millennium Assembly (2000 General Assembly of the United Nations):

1. Eradicate extreme poverty and hunger.
2. Achieve universal primary education.
3. Promote gender equality and empower women.
4. Reduce child mortality.
5. Improve maternal health.
6. Combat HIV/AIDS, malaria and other diseases.
7. Ensure environmental sustainability.
8. Develop a global partnership for development.

The Plan of Implementation from the World Summit on Sustainable Development is more specifically relevant to a GCCFI, because it includes the following statements:

"8. Take joint actions and improve efforts to work together at all levels to improve access to reliable and affordable energy services for sustainable development sufficient to facilitate the achievement of the millennium development goals, including the goal of halving the proportion of people in poverty by 2015, and as a means to generate other important services that mitigate poverty, bearing in mind that access to energy facilitates the eradication of poverty. This would include actions at all levels to... (d) Support the transition to the cleaner use of liquid and gaseous fossil fuels, where considered more environmentally sound, socially acceptable and cost-effective; (e) Develop national energy policies and regulatory frameworks that will help to create the necessary economic, social and institutional conditions in the energy sector to improve access to reliable, affordable, economically viable, socially acceptable and environmentally sound energy services for sustainable development and poverty eradication in rural, peri-urban and urban areas...

49. Reduce respiratory diseases and other health impacts resulting from air pollution, with particular attention to women and children, by... (d) Assisting developing countries in providing affordable energy to rural communities, particularly to reduce dependence on traditional fuel sources for cooking and heating, which affect the health of women and children."

In addition, there has been considerable evolution of thinking about fundamental human rights issues that are

highly relevant to the proposed GCCFI. At the most general level, Mary Robinson, the former UN High Commissioner for Human Rights, has stressed the human rights-based approach to tackling absolute poverty, which she has identified as the world's worst human rights problem[28]. Robinson points out that this approach implies that people have a justifiable expectation that their basic needs of housing, health provision, education, and personal security must be met, and that people are elected or appointed to government office to fulfill those obligations. According to Article 25 of the Universal Declaration of Human Rights – which was affirmed strongly in September 2000 by the largest gathering of heads of state and government, including the United States, in the Millennium Declaration, from which the Millennium Development Goals (MDGs) have been extracted:

> "Everyone has the right to a standard of living adequate for the health and well-being of himself and of his family, including food, clothing, housing and medical care..."

Of these universal human rights, the right to good health is perhaps the most important for the proposed GCCFI. The preamble to the Constitution of the WHO (1946) provides: "The enjoyment of the highest attainable standard of health is one of the fundamental rights of every human being without distinction of race, religion, political belief, economic or social condition."

Robinson [2004] points out that over 60 national constitutions explicitly refer to the right to health or to health care, that there is a growing body of case law at national level, and that:

> "At regional level, there is abundant jurisprudence on the right to health under the European Social Charter, which goes back to 1961. Over the years, the European Committee of Social Rights has carefully monitored access to healthcare in Contracting Parties, and continues to do so... At international level the content of the right to health has been clarified by the Committee on Economic, Social and Cultural Rights in General Comment 14 adopted in 2000. The Committee analyzed the obligations of states as being three-fold: to respect, to protect and to fulfill."

A key aspect of the proposed GCCFI is insistence that governments take responsibility via implementing new clean cooking fuel policies aimed at preventing the health damage arising from indoor air pollution generated in the combustion of solid fuels. One of the most relevant developments over the last decade in support of this approach is the interpretation of the right to health by the African Commission on Human and People's Rights in *World Organization against Torture, Lawyers' Committee for Human Rights and others v. Zaire* (decided at 19th session, April 1996), which holds that the right to health placed a duty on the government of Zaire to provide basic services such as safe drinking water and electricity besides the requirement to supply adequate medicine.

Regarding the setting of aspirational goals such as the various human rights goals described here, the conservative economist F.A. Hayek[29] warned that:

> "... prudence must be exercised in the creation of expectations, lest one incur a duty that one cannot fulfill."

But this warning certainly does not apply to the right to avoid health damage from exposure to indoor air pollution. Making guarantee of this right a societal obligation is easily affordable, offering societal benefits that dwarf the societal costs.

2.3. Policy

New national and international policies will be needed to bring about a GCCFI – giving attention to: (1) expanding existing and/or creating new infrastructures for ensuring the availability of clean fuels and appropriate stoves to both urban and rural regions, (2) finding ways to make clean fuel affordable to all of the 2.6 billion people currently dependent on solid fuels – including the very poorest, and (3) developing capacity to implement the necessary policies and financial arrangements that will be required, both nationally and internationally.

A general discussion of national and international policy issues follows, with a focus on strategies for enabling the very poorest households to reach in 10-15 years' time the highest rungs on the "energy ladder" – which is perhaps the most daunting policy challenge.

2.3.1. National policy

The premier tasks for national policy-makers are to establish goals and timetables for a national clean cooking fuel initiative (NCCFI) and to create, perhaps within an existing institution, an appropriate implementing agency, which we will refer to as the clean cooking fuel bureau (CCFB).

The long-term (10-15 year) goal should be to bring about universal provision of at least a minimal quantity of CCF per household adequate to satisfy basic needs. Establishing such a goal as the cornerstone for the overall effort would by itself be an important signal to investors, who would then begin to mobilize the capital and other resources needed for its realization.

The first task of the CCFB would be to develop a database that would provide the basis for a NCCFI implementation plan, identifying for each region: (1) populations that must be served, (2) candidate fuels and stoves (via technology assessments) that might be provided, (3) infrastructure issues that must be addressed, (4) candidate fuel/stove providers – including scope in fuel/stove distribution for "womentrepreneurs", (5) cost estimates for providing fuels and stoves, and (6) determination of the ability/willingness to pay for clean fuels as a function of income. Policy-makers would then use this information to formulate an appropriate CCF policy.

The CCFB would also develop monitoring and evaluation programmes that would periodically inform policy-makers about progress toward goals and issues requiring policy adjustments. Much of the CCFB effort would be spent on measures aimed at getting CCFs into the poorest households.

Measures that promote universal *access to clean cooking fuels* will help make these fuels more affordable, by driving down costs per unit of fuel sold as a result of economies of scale in the distribution system, if public policy insists that all households have access to clean fuels. However, such cost reductions alone are not likely to be

adequate to provide clean fuels to *all* households, including the poorest.

Historically many countries have addressed the affordability issue by keeping low prices of LPG, kerosene, and other clean energy carriers that are suitable for domestic use – often via cross-subsidies that inflate prices for other petroleum-derived products. Such subsidies are costly and tend to provide much greater benefits for affluent than for poor consumers (who often cannot afford clean fuels even with the price subsidy) and lead to use of the subsidized fuels for unintended purposes (e.g., motor vehicles, swimming pool-heaters, and saunas).

A better approach would be to provide subsidies only to poor households[30]. After eliminating LPG price subsidies in 2002, Brazil introduced an *Auxilio-Gas* ("gas assistance") program that did just this – providing bi-monthly subsidy payments for households that have incomes up to half the minimum wage[31]. In 2003 the new approach provided an annual per capita subsidy to qualifying households (almost 20 % of the population) that amounts to more than 60 % of the retail LPG price – more than twenty times the previous general price subsidy, even though the net government subsidy expenditures are only about half as large[32]. A preferable alternative to cash outlays would be to provide the clean cooking-fuel-equivalent of "food stamps[33]" that could be used only for LPG purchases by qualifying households.

How much subsidy is needed to bring about a high degree of clean cooking fuel use among poor households will vary by region. For the poorest households in some regions the required subsidy is likely to be a substantial fraction of the total cost of fuel (and stoves) at today's high LPG prices – as is illustrated by the recent reversal of the long-term trend away from use of fuelwood in Brazil after the recent removal of LPG price subsidies in favor of the *Auxilio-Gas* program [Lucon et al., 2004].

Despite the many competing demands on the public purse, the provision of subsidies need not be overly burdensome, because overall costs are modest – especially when considered in relation to the benefits provided. Nevertheless, it will be worthwhile to explore promising subsidy strategies that do not require drawing down general public treasury resources.

That new fuels such as DME and ethanol gel are prospectively producible at lower cost than LPG provides the basis for one promising approach for generating revenues to subsidize the provision of clean fuels for the poorest households – taking advantage of the fact that, although LPG often is not affordable by the poorest household, it is still affordable by more affluent households. When such new fuels are first introduced, they will tend to be supply-limited, and their prices would tend to rise to the level of the marginal cost of the primary alternative – which in many parts of world will be the price of imported LPG. Under free-market conditions, this would generate windfall profits for the new fuel provider – prices for these new fuels would not fall under free-market conditions until eventually supply constraints on the new fuels are gone. In such a situation the government might consider levying a tax on the new fuel to tax away all or part of the windfall profits[34].

A general goal for public policy should be to seek the least subsidy needed to provide clean fuel services (for cooking fuel plus stove) to households that cannot afford full retail prices. One approach would be to try to exploit market forces in identifying the least-costly ways to provide the subsidies. This might work as follows: the government could hold an auction for the exclusive right to provide clean cooking fuels in a designated region over a specified time-period and make the winning bidder the cooking service provider who can deliver universal coverage at the least subsidy cost. Similar "negative auctions" have been successful in California in introducing specified quantities of renewable energy supplies[35].

2.3.2. International policy

New international policies are needed to attract foreign investment to the GCCFI. This might be accomplished in at least three different ways, building on progress already made with the LP Gas Rural Energy Challenge[36]: (1) some foreign investors would automatically be attracted to invest in CCFs once NCCFI goals are announced; (2) official development assistance (ODA) support from industrialized countries might be increased in line with the Plan of Implementation from the World Summit on Sustainable Development; and (3) investments might be made by multinational companies seeking low-cost opportunities for climate change mitigation – niche opportunities under the Clean Development Mechanism (CDM) and much larger opportunities later, if and when a full carbon-trading regime emerges.

The first option would require that the host country offer attractive investment opportunities relating to CCFs. For countries that want to attract such investment, a role of the CCFB should be to inform policy-makers as to the conditions most conducive to this activity.

For the second and third options, it is likely that a new entity within an appropriate multilateral agency (e.g., UNDP) would be required – a body that we will call the clean cooking fuel facility (CCFF). The CCFF, with a modest administrative budget, would serve mainly as a conduit for channeling international investment funds to qualifying projects in qualifying countries. The CCFF would define criteria for attracting international support to qualifying projects, which would be in countries that have NCCFIs and CCFBs. The CCFF would transfer funds for qualifying projects to the CCFBs. It would also continually monitor these projects, periodically review them, and make recommendations regarding continuing support by funders in light of such reviews.

Investment in clean cooking fuels should be a prime candidate for ODA. Even if 100 % of the clean cooking fuel cost had to be covered by ODA (which is certainly not the case!) the required aid would be much less than the historical pledge of committing 0.7 % of their GDP to ODA – as noted above. Although recent ODA levels have averaged only 0.2 % of GDP (in part because of concerns that ODA has not been directed to true development needs), the widely growing recognition of the

critical importance of clean cooking fuels to sustainable development (see Section 2.2, "Timeliness", above) suggests that opportunities for increased ODA contributions in this area should not be overlooked.

A body such as the proposed CCFF would probably be necessary if there is to be increased ODA support – both to give donors the confidence that the funds would be spent for the intended purposes and to shield the recipients from (despised) tied-aid constraints that tend to characterize bilateral aid.

The GCCFI could also advance climate mitigation objectives because, as noted, most clean cooking fuel options lead to less greenhouse gas emissions than cooking with coal or biomass. The climate mitigation costs for such investments will often be less than for typical climate mitigation options in industrialized countries. Investment opportunities of this type that are suitable Clean Development Mechanism (CDM) projects should be pursued in the near term. Once full-scale carbon trading is allowed, large-scale investments in clean cooking fuel projects can be expected.

Projects seeking carbon credits would put large responsibilities on the CCFF, working in concert with the CCFBs, to define emission baselines and emission categories that qualify for getting carbon credits, as well as to specify how emission reductions would be verified. Baseline-setting and verification are inherently difficult and prospectively contentious processes. Aiming for a high degree of rigor would be costly and is probably not desirable. Because of the relatively modest amounts of greenhouse gas emissions that are at stake and the large non-climate-mitigation benefits offered by a shift to CCFs, policy-makers may find it desirable to err on the side of overestimating rather than underestimating GHG mitigation benefits for qualifying CCF projects where the there is ambiguity.

3. A way forward

A compelling case has been made for a GCCFI as an intensive North/South, private/public collaboration to bring about universal use of clean fuels for cooking and heating in 10-15 years' time. The time is ripe for a GCCCI – given the momentum of the Millennium Development Goals and the Plan of Implementation from the World Summit on Sustainable Development.

However, a GCCFI will not be launched without strong leadership – from both politicians and corporate leaders in the North as well as the South, and from the multilateral development agencies and NGOs. The issues addressed are on hardly any "radar screens" in the industrialized world and, though of crucial importance to developing countries, have not yet gained political prominence even there because CCFs would benefit mainly women whose voices are still muted in most political settings. CCFs must become a rallying-point on the political agenda – like *bijli* (electricity), *sadak* (roads), and *pani* (water) in the recent Indian elections.

If the needed leadership emerges, one can be optimistic that the daunting goal articulated here can be realized – in large part because the GCCFI is affordable, certainly in relation to the benefits offered but also in an absolute sense. Moreover, success with this extremely important but finite and practically doable initiative can potentially catalyze much grander international collaborative efforts to advance sustainable development goals – a potential that will be widely recognized. ■

Notes

1. Goldemberg and Johansson [2004]. See also Goldemberg et al. [1985] and Goldemberg et al. [1988].
2. The authors estimated 20 years ago that 50 W per capita of clean gaseous cooking fuel is needed as a key element of a comprehensive energy and development strategy that includes substituting modern energy carriers for non-commercial energy sources [Goldemberg et al., 1985]. Here an estimate of the same magnitude is presented on the basis of calculations carried out for China, Brazil, and India, drawing on the information compiled in this special issue of *Energy for Sustainable Development.* For China, calculations carried out for coal-derived dimethyl ether (DME) displacing coal in residences are consistent with an average per capita DME use rate for cooking, water heating, and space heating of 34 kg of LPG-equivalent. For Brazil, the rate of use of LPG in 2002 for households that use LPG was 125 kg per year [Lucon et al., 2004] or 33 kg per capita per year (average household size = 3.8). For India, the rate of use for LPG in 2002 for households that use LPG was 115.1 kg per year [D'Sa and Murthy, 2004] or 22 kg per capita per year (average household size = 5.26).
3. [EIA, 2004].
4. [Reddy et al., 2000]. See also [Goldemberg et al., 1988].
5. [Reddy et al., 2000]. See also [Goldemberg et al., 1988].
6. Small particles (2.5 microns in diameter or less) of particulate matter.
7. See [Smith et al., 2004; Holdren et al., 2000; Ezzati and Kammen, 2001].
8. [Mehta and Shahpar, 2004].
9. See [Holdren et al., 2000; Smith et al., 2000; Edwards et al., 2004].
10. The CO_2 emissions associated with burning 35 kg/capita/year by 2.6 billion people would be ~75 million tC/y – about 1 % of global CO_2 emissions. See, for example, [Smith, 2002].
11. [Mehta and Shahpar, 2004].
12. [Smith et al., 2004].
13. [Mehta and Shahpar, 2004].
14. [Johnson et al., 1997].
15. [Lucon et al., 2004].
16. Assuming the US Energy Information Administration's reference forecast [EIA, 2004] of global oil and natural gas production (increasing 1.6 times and 1.7 times, respectively, 2001-2025) and the same ratios for LPG to primary oil and gas production as in 2001, LPG production in 2025 would be 333 Mt -- 1.64 times the rate in 2001. Assuming that one component of residential demand grows with the global population (an increase of 27 Mt) and that a second component is the estimated 91 Mt required to meet the needs of the 2.6 billion people (at a rate of 35 kg/capita/y) that now use solid fuels, total residential demand for LPG in 2025 would be 215 million tonnes (2.2 times the 1991 value). Under this scenario non-residential demand could grow only 0.6 %/y, to 117 Mt in 2025 -- up from 102 Mt in 2001. For comparison, non-residential demand for LPG grew 2.8 %/y, 1995-2005.
17. Derived from coal and made up mainly of CO and H_2, town gas is clean, but not safe – leakage can lead to deadly CO poisoning --, but town gas can be a bridge fuel on the path to widespread use of clean and safe cooking fuels.
18. [NBS, 2002].
19. [Gu and Duan, 1998].
20. [Reddy, 2004].
21. DME is a clean synthetic fuel with properties similar to LPG. Like LPG, it is a gas at atmospheric pressure that must be stored in mildly pressurized canisters. It can be deployed using infrastructure already established for LPG.
    DME is produced worldwide at a rate of about 150,000 t/y. Some is used as a chemical feedstock; the only consumer market served at present is as an aerosol propellant (e.g., for inhalers) – it replaced for this application the fluorinated hydrocarbons that were banned by the Montreal Protocol. China has been exploring the prospects for DME as a cooking fuel since the 1980s.
    DME can be made with commercially ready technology from stranded natural gas assets [Naqvi, 2002], coal [Larson and Ren, 2003; Celik et al., 2004; Larson and Yang, 2004], or biomass [Ekbom et al., 2003; Klintbom et al., 2003]. Currently two large plants to provide DME for domestic markets from natural gas are under construction: one in China (a 110,000 t/y plant in Sichuan province that will be completed in 2005 [Toyo, 2004] and one in Iran (an 800,000 t/y plant that will be completed in 2006 [Haldor Topsoe, 2004]). And in China planning has begun for a large plant for making DME

from coal (in 2002 China's State Development Planning Commission approved plans for building an 830,000 t/y coal-to-DME plant in Ningxia province, but the schedule for moving ahead with this project is uncertain [Lucas, 2002]).

22. Ethanol, well established as an automotive fuel in Brazil, can also be used in cooking applications. Although direct use of ethanol as a cooking fuel poses safety hazards, a derivative ethanol gel is a safe and clean renewable cooking fuel that is being promoted in several African countries [Utria, 2004].
23. In Brazil ethanol, used for energy purposes mainly as an automotive fuel, has evolved to become an option that is fully cost-competitive with crude-oil-derived gasoline: as a result of continual marginal technological improvements realized via experience, ethanol prices in Brazil have fallen almost by half during the last quarter century (Figure 1). The option of using ethanol in cooking applications (see Note 22 above) should be given wide scrutiny, especially in light of the fact that the ethanol price in Brazil is low enough to compete with LPG in a world with oil prices of $ 30 per barrel (1 barrel = 0.1364 t) or more.
24. It is estimated that DME can be produced from coal with commercially ready technology at plant-gate costs that compare favorably with imported LPG; moreover, the price of coal-derived DME would be stable, whereas the LPG price has fluctuated widely, roughly following world oil price fluctuations [Larson and Yang, 2004].
25. Assuming an average retail price of $ 570/t of LPG-equivalent for serving 2.6 billion people at a rate of 35 kg/capita/year. This estimated average retail price is based on the following: in China, the landed price of LPG is $ 378/t when the crude oil price is $ 30 a barrel [Larson and Yang, 2004]. Truck transport of LPG 1000 km to a typical rural area and bottling/retailing adds a cost of $ 153/t [Larson and Yang, 2004], bringing the retail price to $ 530/t. In Karnataka, India, the retail LPG price in mid-2004 was Rs. 27,650/t or (@ Rs. 45/US$) $ 614/t [D'Sa and Murthy, 2004]. In Brazil, the retail price in 2002 was R$ 26.3 (US $ 8.4) for a 13-kg cylinder [Lucon et al., 2004] or $ 650/t.
26. [Goldemberg and Johansson, 2004].
27. Even # 6, if one includes lower respiratory infections and chronic obstructive pulmonary disease among "other" diseases.
28. [Robinson, 2004].
29. [Hayek, 1988].
30. A well-established and successful precedent is "lifeline" rates for residential electricity consumption: making electricity available at a very low rate (per kWh) for the small amount of electricity needed to satisfy basic human needs, with the rate rising rapidly at higher consumption levels, in such a manner that the average rate is equal to the marginal cost of providing residential electricity.
31. [Lucon et al., 2004].
32. The *Auxilio-Gas* subsidy amounted to US$ 52.1 per qualifying family in 2002 [Jannuzzi, 2004] or about $ 13.7 per capita, so that at the 33 kg/y average per capita residential LPG consumption rate in Brazil and the average retail price in 2002 of US$ 0.65/kg, the subsidy amounted to 64 % of the retail price.
33. In a US program subsidies via food stamps have been provided to ensure access to adequate food for low-income individuals and families.
34. See [Larson and Yang, 2004]. Of course, allowing some windfall profits would be desirable if so doing would accelerate construction of new plants.
35. In California between June 1998 and August 2001 a series of three such auctions were carried out to award 5-year production incentives for the provision of 1300 MW of renewable electricity [Bolinger and Wiser, 2002]. The average cost of the incentive (0.84 ¢/kWh) was much less than for many other types of state incentive programs for advancing renewables.
36. [McDade, 2004].

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