Wood energy and livelihood patterns: a case study from the Philippines

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Trends in the socio-economic role of wood energy in Cebu Province, studied in 1992 and revisited ten years later.

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In many South and Southeast Asian economies, some 20 to 80 percent of the energy demand is met by wood. Woody biomass tends to be used in traditional ways. For the most part, the entire system from production to consumption of woodfuel comprises informal unregistered activities involving several sectors of the community. In areas that have a market for woodfuel, its production, distribution, trade and consumption reflect a flow that has proved its efficiency through time. However, in some other areas where there is no such market, woodfuel has not become commoditized.

Woodfuel is not only used in poor and rural households. In many towns and metropolitan areas, woodfuel is widely used either as main, substitute or supplementary fuel by low-, middle- and high-income groups.

In the Philippines, fuelwood, charcoal and other forms of biomass energy make a major contribution to meeting the energy requirements of the population. The collection, distribution and trade of these fuels also provide income and employment to millions of Filipinos. Despite this importance, relatively little is known about how woodfuels are produced, managed, traded and consumed in the country. No single government agency is in charge of developing policy regarding woody biomass energy, since woodfuel is often considered inferior and a major cause of deforestation and environmental degradation.

This article illustrates the socio-economic role of wood energy in the Philippines through the results of a case study carried out in Cebu Province in 1992 and revisited in 2002.

CEBU

The island province of Cebu is situated in the central Philippines, about 550 km southeast of Manila, the capital. It is a narrow strip of land about 5088km^2 in area, stretching 220km from north to south and only 40 km in breadth at its widest point. It has a total population of 3.356 million, consisting of about 676 000 households with an average household size of five people and a population density of 660 persons per square kilometre (National Statistics Office, 2002). Its capital, Cebu City, is the second largest city in the Philippines.

Cebu is characterized as the trade and industry hub of the central and southern Philippines, since only about 30 percent of the land is suited for agriculture. Approximately three-fourths of Cebu's land area has a slope of more than 18 percent, and much of the island is dominated by a central mountain range that rises to over 1000m above sea level (Provincial Planning and Development Staff, 1987). During the nineteenth century, Cebu was already the focal point for trade and economic networks for the Visayas and Mindanao (the central and southern island groups of the Philippines), linking them to markets in Manila, the United States and Europe (*Cebu Yearbook*, 2002).

Cebu is unique in the fact that this island province has long been deforested. The World Bank (1989) reported that Cebu was 99.6 percent deforested. As long ago as 1870 the island was reported to be 94 percent deforested (Ahern, 1901; Poffenberger, 1990). If Cebu is known to have had no pristine forest for at least the past century, how is it that the woodfuel industry appears to be thriving? How is it that hundreds of families depend on the wood energy industry to provide them with incomes and livelihood activities? Where do the wood resources come from and for what are they used? Who are the key players? What socio-economic contribution does wood energy provide to the local economy?

WOODFUEL IN CEBU

Residential, commercial and industrial uses

Woodfuel is a major source of energy in the province, particularly as household cooking fuel.[1] Reasons include its affordability (it is also gathered free in some cases) and the taste and preference of consumers. It is also used as a reliable supplemental and/or backup fuel. Some households, however, do not use woodfuels or are reducing its use because of its inconvenience, smoke and messiness.

In the commercial and industrial sector, a large number of prepared-food vendors such as restaurants, vendors of barbecue and *lechon* (traditional roasted pig, served at celebrations and increasingly sold commercially), bakeries, makers of *poso* (rice steamed in coconut leaves) and noodle factories depend on woodfuel. Institutions such as hospitals, schools and prisons and industries such as blacksmiths and iron gate manufacturers, fashion accessory manufacturers and rattan furniture makers are among the highest consumers of scrap wood, coconut wood and charcoal.

Production and management

Contrary to common belief, not all woodfuel is sourced from natural forests. Woodfuel production takes place within several types of land use, such as tree fallow and shrub fallow, woodlots, tree plantation sites, reforestation sites, agroforestry systems (fruit trees or scattered trees) and brushland and shrubland areas. Most of the woodfuel production in Cebu originates from a handful of species: *Leucaena leucocephala, Leucaena glauca, Gliricidia sepium*, *Gmelina arborea* and *Swietenia macrophylla.* The practice of coppicing is found among many woodfuel producers, but woodfuel coppice lands are declining as a result of land conversion, e.g. real estate development and establishment of mango plantations. Woodfuel coppice lands are normally harvested in rotational patches every two to five years. Trees are cut and carried or transported to leveled areas where they can be split, bundled according to size of fuelwood or converted into charcoal.

In Cebu, charcoal makers generally use local techniques. In the *ham-ak* method, wood is piled on a slope above ground and then covered with grass, weeds, banana leaves and a layer of soil before fire is put to it. In the *tinabonan* approach, a charcoal pit is dug on a slope, filled with wood and covered with a metal sheet after lighting. The *ham-ak* approach generates more and better-quality charcoal, but requires close monitoring, 24 hours a day over two to three days. *Tinabonan* has the advantage of requiring less attention.

Trade and distribution

In Cebu, trade in woodfuel has been a thriving and sustainable informal-sector industry for at least five decades. The rural-to-urban trading and distribution network (see Figure), involving numerous intermediaries at various levels, provides income, jobs and livelihood to hundreds of families both in the countryside and in the urban centre. The system of woodfuel trading in the province varies depending on the location and distance of woodfuel production sites, the presence of growers, manufacturers, rural and urban traders, the type of fuel being traded and regulatory policies governing transport of woodfuel. In general, the woodfuel marketing system in Cebu appears to be competitive and efficient.

The existence of local woodfuel entrepreneurs willing to engage in the business is one decisive factor in determining the extent of biofuel production in a given area. Woodfuel trade in the province provides income and employment to an estimated 45000 to 65000 people. In general, the woodfuel marketing system in Cebu appears to be competitive and efficient. Roughly 150000 to 200000 tonnes of fuelwood (including coconut fronds) are sold per year, and roughly 40000 to 50000 tonnes of charcoal. The value of commercial biofuel trade in the province is between US$9.3 million and $12 million per year, and Cebu is only one of more than 60 provinces in the country (although the use and production of biofuels may vary among provinces).

Charcoal making and biofuel trade and distribution also provide seasonal income in many areas of the province, particularly for farmers whose primary income comes from growing and trading mangoes.

E. REMEDIO

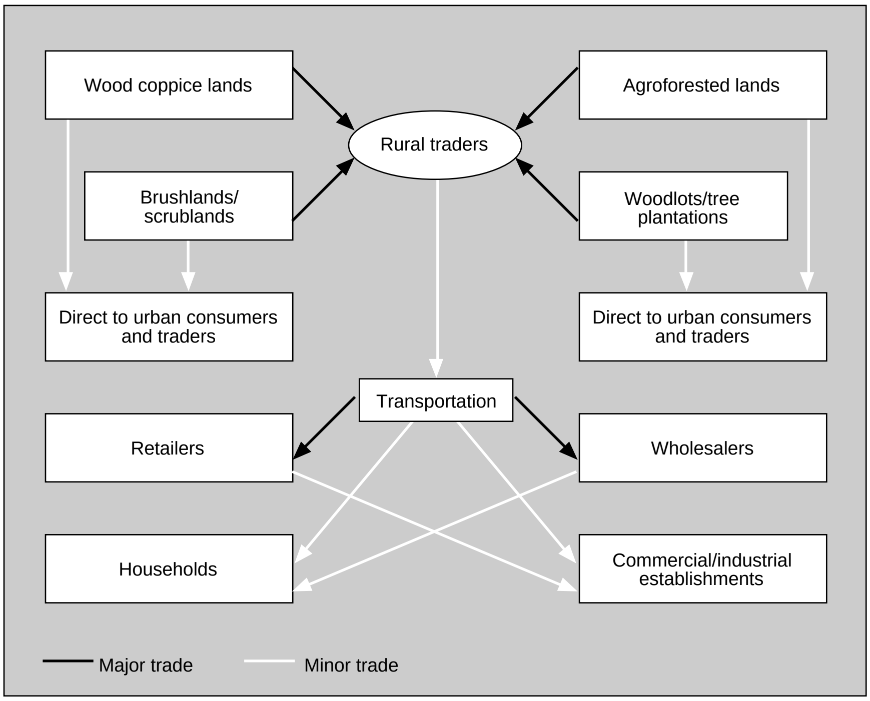
Coppicing of **Gliricidia** *and* **Leucaena** *species is a common practice among woodfuel producers in Cebu Province, the Philippines; here, rapid regrowth of the coppiced stumps is visible just five weeks after harvest, with smaller branches left on the slope*

WOOD ENERGY TRENDS IN THE CITY AND PROVINCE OF CEBU, 1992 TO 2002

A 1992 study looked into the patterns of production, consumption, trade and distribution of woodfuel on the island of Cebu

[1] The use of other biomass residues besides wood is not great except for coconut fronds. Hence, the terms woodfuel and biofuel (also wood energy and bioenergy) are used interchangeably throughout the text.

In Cebu, woodfuel trade has been a thriving informal-sector industry for decades, providing income and employment to thousands of entrepreneurs: Left, sacks of charcoal of various quality grades and from different tree species displayed for sale in a typical urban charcoal market, Cebu City; Centre, an urban woodfuel trader selling sacks of scrapwood and wood shavings, Cebu City; Right, a fuelwood vendor's display, Cebu City



Woodfuel trade and distribution flow

(Bensel and Remedio, 1993). It came to an eight-point conclusion:

- Fuel choice decisions among urban households were strongly affected by income levels, although taste preferences and stove costs were also important.
- A fuel-switching trend away from woodfuel towards liquefied petroleum gas (LPG) and kerosene was already observed. The use of multiple fuels among households and commercial establishments was also prevalent.
- The commercial and industrial sector depended slightly less on woodfuel than did households, although woodfuel was used by many businesses, particularly food vendors and barbecue stalls.
- Most woodfuel came from planted trees and managed agricultural lands. Major species grown were *Leucaena leucocephala* and *Gliricidia sepium*.
- Coppicing was the main harvesting practice, done on a two- to five-year rotation basis.
- The rural woodfuel marketing and transport system was highly competitive and a major source of employment.
- The urban woodfuel market also included hundreds of urban woodfuel

Gender implications of wood energy use in developing countries

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In developing countries, fuelwood collection is almost entirely dominated by women and children (shown, India)

Rural energy, household time allocation, health, nutrition and gender form a web of complex interrelated issues that merit serious attention in the formulation of development strategies.

Energy is a basic human need, and in many regions of the world the burden of energy poverty is borne by women and children (FAO, 1999a). It is usually the women and children who spend long hours collecting fuelwood, often foregoing other valuable activities such as farming, education, recreation and rest.

Recent studies (FAO, 1999b) comparing perceptions about the labour involved in urban and rural woodfuel systems revealed gender-sensitive distinctions in the definition of heavy versus light work and safe versus risky work conditions.

Group discussions with communities in FAO's Regional Wood Energy Development Programme for Asia and the Pacific revealed that woodfuel-related tasks exclusively done by men – tree climbing, tree felling, cross-cutting large trunks of trees and long-distance transport using conveyances such as tractors, bullock carts and hand cars – tend to be considered heavy. Fuelwood gathering for home consumption and subsistence is considered a light task, even if women walk long distances with heavy head loads for hours; head loading is exclusively done by women. Heaviness therefore appears to be related not to the weight of the load, but to the strength of the gender performing the task.

The tasks carried out by men in cutting fuelwood are considered risky and dangerous, hence not safe for women to perform. Inhaling heavy smoke while cooking, which adversely affects health, and head loading are not considered risky or dangerous. The general observation was that whenever trading or cash was involved, women's safety was a concern. However, most activities related to trade or distribution of biofuel for cash in some kind of market, including collection and transport, do not usually involve women. On the other hand, the domestic use of fuelwood, from production and collection up to consumption, is almost entirely dominated by women and children. No cash involved – only women and children's labour.

retailers and wholesalers, and was quite competitive.

- Woodfuel policy on Cebu was premised on the belief that woodfuel was a major contributor to environmental degradation on the island. The research results suggested that this was not really the case, and policy changes were recommended.

In contrast, a follow-up study ten years later (Remedio and Bensel, 2002) indicated the following trends:

- Households are tending to switch from so-called inferior fuels (e.g. fuelwood) to premium fuels (e.g. LPG).
- LPG is now the most important cooking fuel among households because it is perceived to be relatively affordable, convenient to use, clean and efficient. However, the use of multiple fuels among households continues.
- The use of fuelwood as primary household cooking fuel in Cebu City has declined from 31.8 percent in 1992 to 23 percent in 2002, and the use of fuelwood as a secondary fuel has also declined, from 45.9 to 36.7 percent (Table 1).
- Charcoal as a primary residential cooking fuel declined from 5.6 to 3.4 percent from 1992 to 2002. However, the use of charcoal as a secondary fuel increased from 53.4 percent in 1992 to 67.3 percent in 2002 (Table 1).
- Household income is still a determinant of household fuel choices. Higher-income households on the whole prefer to use LPG and/or electric cooking devices (rice cookers). However, most lower-income households that could not afford LPG in 1992 could afford it in 2002, which suggests that financial obstacles to obtaining LPG have been eliminated or at least reduced.
- Total household fuelwood use in Cebu City declined from 55480 tonnes in 1992 to 53492 tonnes in 2002. In contrast, household charcoal consumption in the city increased from 7966 tonnes in 1992 to 8781 tonnes in 2002

(Table 2). In the industrial/commercial sector, the decline in fuelwood use has been more pronounced, from 16 046 tonnes in 1992 to 6 596 tonnes in 2002, particularly because of the switch away from fuelwood among eateries, bakeries and restaurants. In some cases, the switch was due to restrictions related to smoke emissions in public places. Charcoal consumption increased also in this sector, from 6618 tonnes in 1992 to 14 261 tonnes in 2002.

- The woodfuel industry and trade in the province is still a significant source of income and employment.

TABLE 1. **Primary and secondary household cooking fuels used at all income levels, Cebu City, the Philippines, 1992 and 2002**

Fuel type	As primary fuel				As secondary fuel			
	1992 (*n*=603)		2002 (*n*=379)		1992 (*n*=603)		2002 (*n*=379)	
	No.	%	No.	%	No.	%	No.	%
Fuelwood	171	31.8	87	23.0	277	45.9	139	36.7
Charcoal	32	5.6	13	3.4	322	53.4	255	67.3
Kerosene	115	19.9	77	20.3	183	30.3	126	33.2
LPG	225	38.0	194	51.2	251	41.6	207	54.6
Electricity	4	1.0	7	1.8	60	10.0	94	24.8
Others	56	3.7	1	0.3	–	–	61	16.1
Total	603	100.0	379	100.0	1 093	–	882	–

Source: Remedio and Bensel, 2002.

TABLE 2. **Summary of household biofuel consumption for Cebu City, the Philippines, 1992 and 2002**

Fuel type	Estimated total household use *(tonnes/year)*		Household consumption rate *(kg/household/year)*				Per capita consumption rate *(kg/person/year)*			
	1992	2002	All users		Primary fuel users only		All users		Primary fuel users only	
			1992	2002	1992	2002	1992	2002	1992	2002
Fuelwood	55 480	53 492	1 183	988	1 757	1 155	204	204	303	239
Charcoal	7 966	8 781	109	74	380	228	19	15	65	47

Source: Remedio and Bensel, 2002.

CONCLUSION

The consumption, production and trade of woodfuel continues to be an important source of livelihood in the Philippines. The use of multiple fuels has a long tradition, and woodfuel is used as either primary or secondary fuel at the household level.

The case study of Cebu is a good example. Despite the rapid urbanization of Cebu City, thousands of households in the City and Province of Cebu continue to depend on woodfuel as their primary or secondary cooking fuel. Commercial and industrial food preparation establishments also largely depend on woodfuel. The intricate, multilevel woodfuel system provides income and jobs for thousands of families and saves the economy millions of dollars in foreign exchange every year by preventing the need for imported fossil fuels.

Notwithstanding the significance and importance of bioenergy in both local and national economies, there is still a need to improve the productivity and efficiency of woodfuel production as it impacts on the environment. Likewise, government policies on the cutting and transport of fuelwood need to be reviewed. While many of these policies may be intended to underscore environmental conservation goals, some regulations involving transport permits and protected areas tend to discourage woodfuel producers from more efficient and sustainable management of forest and tree resources. ◆

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Bioenergy and job generation

J. Domac

Employment opportunities from wood energy vary with the context and scale.

Varying conditions and a lack of relevant data make it difficult to apply standard methods for appraisal of employment and earnings from bioenergy, especially when more sophisticated theories are applied such as those including induced effects and multiplier effects.

Formal-sector employment opportunities include both direct employment, comprising jobs involved in fuel or crop production, in the construction, operation and maintenance of conversion plants and in the transport of biomass; and indirect employment, comprising jobs generated within the economy as a result of expenditures related to biofuel cycles (Faaij, 1997).

Human labour required for the production of biomass resources is about five times higher than that needed for the production of fossil fuels. An analysis from Brazil has shown that charcoal production contributes to national employment with some 200 000 to 300 000 jobs (de Carvalho Macedo, 2002).

The employment opportunities vary with the scale of the operation. A landowner who heats the family home and farm buildings with a wood-fired system will probably harvest the fuel supply from the family's own woodlot using the family's own labour. There are no wages involved, only "sweat equity". The same landowner may also benefit from the sale of wood or from renting out equipment for production. In many countries agroforestry is becoming more widespread, with trees considered another crop in addition to grains, vegetables or forage crops (Hector, 2000).

Do bioenergy systems provide earnings that are high enough to make it worthwhile to mobilize local resources to implement them? It is assumed, and possibly generally true for rural conditions, that some of the required resources (e.g. labour, machines, forests or forest residues, land, infrastructure and management capacity) would otherwise not be fully utilized. Moreover, the work is generally not performed under wage contracts, but by self-employed farmers, forest owners or local contractors whose interest is to get adequate earnings regardless of the source (whether personal labour, rental of machines or sale of biofuel).

Job creation in bioenergy involves relatively low investment costs. Studies carried out in Brazil showed that bioenergy industries require an investement of between US$15 000 and $100 000 per job generated, compared with about US$800 000 per job in the petrochemical industry and over $10 million per job for hydropower (Carpentieri, Larson and Woods, 1993) (see Table 1).

Although biomass-based employment has an impact primarily in rural areas of developing countries, it is also important in cities and in developed countries. European policy-makers recognize that renewables (in this case bioenergy) offer potential for employment creation in addition to environmental benefits. The renewable energy industry is one of Europe's fastest

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In Brazil, charcoal production contributes significantly to national employment – shown, charcoal workers amassing wood scraps in the Tailandia region

growing sectors. A study carried out in 1998-1999 predicted that in the European Union the use of renewable energy technologies, including bioenergy, will more than double by 2020, and that this increase will lead to the creation of more than 800 000 jobs in the bioenergy sector by 2020 (Directorate General for Energy of the European Commission, 1999). The use of biomass for power or heat has the potential to create 323 000 jobs by 2020, while 515 000 jobs could be created in the provision of energy crops or forest or agricultural wastes as fuel. This predicted employment impact is far greater than that for other renewable energy sources (Table 2). The analysis assumed that expansion of biological fuel sources occurs without displacing employment in conventional agriculture and forestry. However, constraints pertaining to significant capital costs (Sims, 2002), the high cost of education and the availability of commercial technology all have to be overcome.

In closing, it should be noted that at the local level bioenergy production and use may have other significant implications besides employment and monetary gains (social, cultural and environmental) which are not tractable to quantitative analysis and are therefore omitted from most impact assessments.

TABLE 1. **Investment cost of employment in different energy sectors, northeastern Brazil**

Field of job creation	Investment cost per job created *(thousand US$)*
Tree planting for electricity production	15-100
Ethanol agro-industry	12-22
Industrial projects	40
Petrochemical industry	800
Hydropower	10 000

Source: Carpentieri, Larson and Woods, 1993.

TABLE 2. **Predicted impact on employment from bioenergy and from other renewable energy technologies, European Union (new net full-time jobs relative to 1995 base)**

Energy type	2005	2010	2020
Solar thermal heat	4 590	7 390	14 311
Photovoltaics	479	-1 769	10 231
Solar thermal electric	593	649	621
Wind onshore	8 690	20 822	35 211
Wind offshore	530	-7 968	-6 584
Small hydro	-11 391	-995	7 977
Bioenergy	449 928	642 683	838 780

Source: Directorate General for Energy of the European Commission, 1999.

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Biomass energy, indoor air pollution and health

A. Koopmans

Households that use biomass energy require efficient stoves to reduce smoke, particles and gases that are hazards to the health of women and children.

Biomass (wood, charcoal, agricultural residues, dung, etc.) is widely used as a source of energy in developing countries. Rough estimates indicate that worldwide one-third of the population or about 2 billion people depend on these sources of energy (UNDP/UNDESA/WEC, 2000). Biomass energy is used primarily to cook food, mainly using traditional or improved stoves (but also open fires). However, wood stoves may at the same time also be used as space heaters, as lamps, to repel insects, to preserve thatched roofs, to dry crops and fish, and so on. The simple wood stove is an integral part of the household, which is rarely true of modern stoves. This may be one of the reasons why it has been difficult to introduce better stoves or to change the cooking environment.

Improvements are needed, however, as evidence gathered over the past two decades shows that traditional multifunctional wood- or other biomass-burning stoves are not very efficient and that they often emit considerable amounts of smoke, soot, particulates and many kinds of harmful gases, which are potentially hazardous products of incomplete combustion (PICs). As a result, the cook – usually a woman – and small children in the home are exposed to high levels of indoor air pollution.

Results from studies carried out in developing countries indicate that particulate concentrations from traditional biomass-using stoves are often ten or more times higher than the standards set by the United States Environmental Protection Agency (Albalak *et al.*, 1999). Exposure to these high levels of pollution has been consistently associated with acute respiratory infections, the largest single-category cause of morbidity and mortality worldwide (Smith *et al.*, 2000). Evidence links exposure to biomass fuel combustion with chronic obstructive lung disease, tuberculosis, cataracts and adverse pregnancy outcomes (Albalak, Frisancho and Keeler, 1999; Perez-Padilla *et al.*, 1996; Mishra, Retherford and Smith, 1999; Mohan *et al.*, 1989; Mavlankar, Trivedi and Gray, 1991). The World Health Organization (WHO) has estimated that as many as 2 million people in developing countries, the majority under five years of age, die prematurely every year from exposure to the combustion products of household solid fuels (Albalak *et al.*, 2001). The environmental burden of disease caused by indoor air pollution is second only to problems of water and sanitation (see Figure).

Besides being hazardous to human health, PICs are at the same time greenhouse gases. Thus reducing PIC levels will not only benefit health but also reduce greenhouse gases at the same time.

One of the easiest measures for reducing indoor air pollution, widely used in some Asian countries, is the installation of a chimney or a hood over the stove. This will reduce indoor air pollution but not air pollution in general, and it will not help in reducing greenhouse gases. Disadvantages include the cost, the potential for water leakage at the point where the chimney or hood vents through the roof, and the potential fire hazard if the roof is made from a combustible material such as leaves or thatch – therefore this system is not always used.

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Improved stoves provide more complete combustion and thus reduce air pollution in the household, but they need to be easy to use, cheap and durable:
Above, a traditional wood-burning stove, Senegal;
Below, an improved metal wood-burning stove, Senegal.

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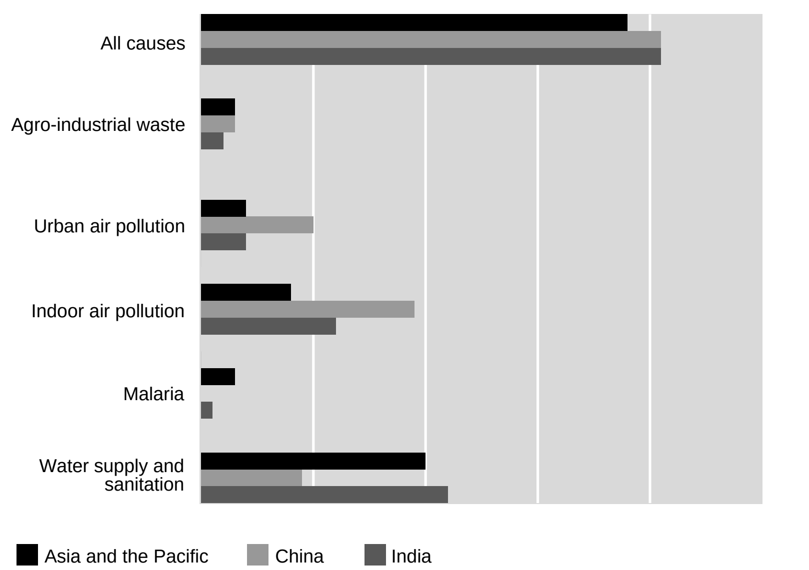
Burden of disease from major environmental risks (% of total DALYs in country or region)



Note: Burden of disease is expressed in Disability Adjusted Life Years (DALYs), a concept that combines life years lost as a result of premature death and fractions of years of healthy life lost as a result of illness or disability. A weighting function that incorporates discounting is used for years of life lost at each age to reflect the different social weights that are usually given to illness and premature mortality at different ages. For example, the death of a baby girl represents a loss of 32.5 DALYs, and a female death at age 60 represents 12 lost DALYs. Values are slightly lower for males (World Bank, 1999).

A switch to other less-polluting fuels such as commercial sources of energy (liquefied petroleum gas, kerosene, electricity, etc.) is another option. However, the cost of the stoves needed as well as of the energy itself is generally considered a barrier to the widespread adoption and use of these other energy sources by a large part of the population in developing countries.

A third option is to improve the stoves used. Initially this process was only technology driven, and improved stoves were not widely adopted (UNDP/UNDESA/WEC, 2000). Stoves need to be not only technologically efficient, but also easy to use, cheap and durable, if possible multifunctional, and usable with multiple fuels – in short, non-technical issues are equally, if not more, important.

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Wood energy, carbon sinks and global climate change[1]

Evidence for global climate change is accumulating, and today there is a growing consensus that the most important cause is humankind's interference in the natural cycle of greenhouse gases, especially carbon dioxide (CO_2). Since the beginning of the twentieth century the atmospheric concentration of greenhouse gases has increased from roughly 300 to 360 parts per million, and the two main causes have been identified as:

- burning of fossil fuels such as oil, coal and natural gas;
- land use change, particularly deforestation.

Using more bioenergy can help reduce dependence on fossil fuels and resulting emissions. In addition, plantation of trees and sustainably managed forests, including those managed for woodfuel, can help avoid or reverse deforestation and can offset carbon emissions by serving as carbon "sinks".

Plants capture CO_2 from the atmosphere and release oxygen through photosynthesis. Some of the CO_2 is lost through respiration, but a major part is sequestered in living and dead organic matter, for instance in wood, wood products and soils. While burning fossil fuels releases CO_2 that has been locked up for millions of years, burning biomass simply returns to the atmosphere the CO_2 that was absorbed as the plants grew. Under sustainable management, this CO_2 is again recaptured by the growing forest, and there is no net release of CO_2.

If an area of non-forest land is converted to forest, additional CO_2 will be removed from the atmosphere and stored in the tree biomass. The carbon stock on that land increases. However, the newly created forest is a carbon sink only while the carbon stock continues to increase. Eventually an upper limit is reached where losses through respiration, death and disturbances from fire, storms, pests, diseases or harvesting approximately equal the carbon gain from photosynthesis.

Harvested wood from these forests is converted into wood products, which also act as a sink until the decay and destruction of old products matches the addition of new products. Since harvest cannot be increased beyond a sustainable limit, the forest and the products derived from it have a finite capacity to store CO_2 from the atmosphere; they act as a perpetual carbon store only when managed sustainably, and otherwise release the carbon previously fixed.

If biomass, including wood, is substituted for fossil fuels, however, land used for sustainable biomass and bioenergy production can continue to provide emissions reductions indefinitely. Often there are opportunities for synergy between bioenergy and wood production and management of forests as carbon sinks, particularly on a regional scale. An example of synergy is that found in integrated management for wood, carbon sequestration and bioenergy, in which the stand is thinned to maximize the combined value of wood production and carbon sequestration, and where cleanings, precommercial fellings and logging residues are used for bioenergy.

Fossil energy is usually consumed in producing bioenergy, for instance during felling of trees in the forest or hauling of timber, but research shows that usually the energy used is a small fraction of the energy produced – roughly 25 to 50 units of bioenergy are produced for every 1 unit of fossil energy consumed in production. Net carbon emissions from generation of a unit of electricity from bioenergy are 10 to 20 times lower than emissions from fossil fuel-based electricity generation.

The approximate global potential for biological mitigation of climate change has been estimated as 100 gigatonnes of carbon by 2050, approximately 10 to 20 percent of total estimated fossil fuel emissions during that time. Roughly two-thirds of this carbon storage could occur in forests.

Ultimately, carbon stocks in vegetation will reach ecological or practical saturation. This potential might be achieved at the same time as greater bioenergy production is realized, with much of the future bioenergy supply probably coming from some of the newly created forests or adapted agricultural systems. It is estimated that bioenergy has the potential to reduce global CO_2 emissions in the year 2050 by up to 25 percent of projected fossil fuel emissions, with a potential for further increases thereafter.

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[1] Adapted from: Matthews, R. & Robertson, K. 2001. *Answers to ten frequently asked questions about bioenergy, carbon sinks and their role in global climate change,* prepared by the International Energy Agency (IEA) Bioenergy Task 38, "Greenhouse Gas Balances of Biomass and Bioenergy Systems". Graz, Austria, Joanneum Research. Available on the Internet: www.joanneum.at/iea-bioenergy-task38/ publication/ task38faq.pdf. For further details please contact: bernhard.schlamadinger@joanneum.at or dieter.schoene@fao.org.