



# Bundles of energy

The case for renewable  
biomass energy

Duncan Macqueen and Sibel Korhaliller

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Cover photo: Woodchip burning in the combustion chamber of the Western Wood Energy Plant at Port Talbot, Wales. Mike Goldwater.

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# Acronyms

AC	Alternating current
BEST	Biomass Energy Strategy, Malawi
BGPP	Biomass gasifier power projects
BRIC	Brazil, Russia, India, China
CASE	Commission for Additional Sources of Energy, India
CDM	Clean Development Mechanism
CEA	Central Electrical Authority, India
CEN	European Committee on Standardisation
CO <sub>2</sub>	Carbon dioxide
Danida	Danish International Development Agency
DC	Direct current
DECC	Department of Energy and Climate Change, UK
DF	Dual fuel
DFID	Department for International Development, UK
DGIS	Directorate General for International Cooperation, Netherlands
DNES	Department for Non-conventional Energy Sources, India
EJ	Exajoules (10 <sup>18</sup> joules)
EnDev	Energising Development Programme
ESRC	Economic and Social Research Council
ESPA	Ecosystem Services and Poverty Alleviation Programme
EU	European Union
EUEI-PDF	EU Energy Initiative Partnership Dialogue Facility
EurepGAP	European Good Agricultural Practices
FAO	Food and Agriculture Organization of the United Nations
FGLG	Forest Governance Learning Group
FSC	Forest Stewardship Council
GEF	Global Environment Facility
GHG	Greenhouse gas
GJ	Gigajoules (10 <sup>9</sup> joules)
GNESD	Global Network on Energy for Sustainable Development
GTC	Grameen Technology Centres
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit
GW	Gigawatt (10 <sup>9</sup> watts)
HPG	High pressure gas
HTU	Hydrothermal upgrading
IDCOL	Infrastructure Development Company Limited, Bangladesh
IEA	International Energy Agency
IFMSLP	Improved Forest Management for Sustainable Livelihoods Programme
IIED	International Institute for Environment and Development
kW	Kilowatts (10 <sup>3</sup> joules)
LPG	Liquefied petroleum gas
LUCE	Levelised unit cost of electricity

MDG	Millennium Development Goals
MJ	Megajoules (10 <sup>6</sup> joules)
MNES	Ministry of Non-conventional Energy Sources, India
MW	Megawatt (10 <sup>6</sup> watts)
NAPA	National Adaptation Programmes of Action
NERC	Natural Environment Research Council
NGO	Non-government organisation
Norad	Norwegian Agency for Development Cooperation
ODA	Overseas development assistance
OECD	Organisation for Economic Co-operation and Development
ORED	Office of Renewable Energy Deployment
PEFC	Programme for the Endorsement of Forest Certification
PIC	Products of incomplete combustion
PPA	Power Purchase Agreement
PPD	Partnership and Project Development
ProBEC	Programme for Biomase Energy Conservation
PV	Photovoltaic
RAP	Regional Advisory Panel
RE	Renewable energy
REDD	Reducing Emissions from Deforestation and Degradation
RET	Renewable energy technology
ROC	Renewable Obligation Certificate
SAN	Sustainable Agricultural Network
SDC	Swiss Agency for Development and Cooperation
SHS	Solar home systems
SIDA	Swedish International Development Agency
SMFE	Small and medium forest enterprise
SMiE	Small and micro enterprise
SWH	Solar water heater
TPES	Total primary energy supply
TREC	Tradable renewable energy certificates
UN	United Nations
UNDP	UN Development Programme
USAID	United States Agency for International Development
W	Watt



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This idea for this report arose from Indian and African Regional Advisory Panels (RAPs) in which partners of IIED recommended that the IIED's Forest Team should develop a specific body of work on forests and energy. The recommendation resonated with findings from long-standing IIED Forest Team work in support of small and medium forest enterprises (SMFEs) through the IIED and UN Food and Agriculture Organization (FAO) co-managed Forest Connect alliance, and through a similarly long-standing body of work under the Forest Governance Learning Group (FGLG), in which forest energy issues were seen to be key drivers of change internationally in the forest sector.

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Following the establishment of a specific Forests and Energy sub-objective within the IIED institutional strategy an opportunity emerged through a call for proposals from the UK ESPA programme for a Partnership and Project Development (PPD) grant to build a consortium around a project on 'Biomass energy – Optimising its contribution to poverty reduction and ecosystem services'. The report was prepared as one of two international background papers to complement country-specific reports from India, Kenya and Malawi for a planning meeting on 19-21 October 2010. The authors are grateful for the active discussion of the draft ideas by participants of that meeting.

The authors are grateful for the inputs and comments on drafts from (in alphabetical order) Steven Hunt, James Mayers, Pavithra Natarajan, Keith Openshaw, Sona Prakash and Jeremy Woods. Sincere thanks are also extended to Mike Goldwater for the photographs, Nicole Armitage and Khanh Tran-Thanh for handling the proofreading, design and production process, and Eileen Higgins for design and layout.

## Executive summary

Taking biomass energy seriously makes increasing sense. Biomass energy currently makes up 77 per cent of the world primary renewable energy mix – or 10 per cent of the world primary energy mix (where primary energy refers to the direct use at source, or supply to users, of crude energy, that is energy that has not been subjected to any conversion or transformation process). But the International Energy Agency (IEA) predicts that biomass will become increasingly important as a source of energy, rising to 30 per cent of the world primary energy mix by 2050. Since non-OECD countries are disproportionately (26 per cent) dependent on biomass energy now, mostly for cooking and heating dwelling spaces, they could capitalise on this trend. By acting now to legalise and make existing biomass energy value chains sustainable, such countries could create a platform for more advanced biomass energy options in the future such as electricity generation or the production of second generation biofuels.

Biomass energy has significant advantages that add to calls to take it more seriously in national energy planning. It is locally accessible in even the poorest nations and communities and its development can ease balance of payments deficits and foster energy security. Over a full life cycle (from the planting of the biomass crop to its ultimate conversion to energy) biomass is low carbon provided (i) it is harvested from sustainable sources on a perpetual basis in which upfront emissions from harvesting and transport are minimised and (ii) it is burnt efficiently to reduce products of incomplete combustion (PICs). It can therefore displace the emissions from fossil fuels in the long term. Biomass energy is very flexible, and can already be converted into all the major energy carriers (heat, electricity, liquid or gas) at a range of commercial scales. While its competitive advantages for heat (either for cooking or dwelling spaces) are well known, conversion processes to electricity, liquid and gaseous fuels are now also becoming competitive. Biomass energy is also labour intensive per unit energy produced in comparison with energy alternatives and can boost rural employment – with the obvious caveat that it is important to assure adequate employment conditions of those involved (salary, health and safety, and so on).

The aim of this report is to review some key biomass energy issues in order to inform forest and energy decision makers in non-OECD countries. It covers:

- the emerging biomass energy boom,
- its advantages and disadvantages as an energy source,
- how it compares with renewable alternatives,
- how to develop policy frameworks that optimise its impact on poverty reduction and the preservation of ecosystem services (including climate change mitigation).

It draws on a global literature, but with particular attention to Europe (especially the United Kingdom) and Africa (especially Malawi) where the authors have experience in greater depth. It does not aim to be comprehensive in its coverage, but rather seeks to stimulate interest in the topic in order to promote serious discussion about how to develop a more sophisticated understanding of, and approach towards, biomass energy in the service of national interests.



The pace and scale at which biomass technology is developing is impressive, if somewhat restricted to OECD countries and, notably, some of the 'BRICs' (Brazil, Russia, India and China). The use of biomass need no longer be labelled as 'dirty', 'traditional', 'non-commercial' or 'unsustainable'. New technological advances make it 'clean', 'modern', 'highly-commercial' and potentially 'sustainable'. State of the art programmes to reach national carbon neutrality in energy production in Denmark by 2050 have a doubling of biomass energy as a central component. In Austria, 80 per cent of new homes are equipped with wood pellet boilers, most with automatic 'fit-and-forget' feed systems. In the United Kingdom, the paltry 1 million tonnes of biomass currently burned (including co-firing) would expand to 50-60 million tonnes per year if all 7GW-worth of biomass-to-electricity power stations that have received planning permission are financed and built. Demand for biomass from these power stations would exceed available UK production of biomass, estimated at 10 million tonnes per year, by as much as 5-6 times (even if the exact total is highly dependent on complex existing markets for agricultural and forest crops and residues).

Exactly what type of biomass energy will be demanded in the future (such as heat, electricity or liquid transport fuels) and where the supply will come from is an open question. Certainly some of the supply will have to come from new dedicated energy crops either integrated within multi-functional agricultural landscapes or on marginal or surplus agricultural land, since existing agricultural and forest residues alone are unlikely to meet future demand. Quite how that will be done requires urgent attention. It is not always the case that food crops are in direct competition with energy crops and there may be ways of augmenting energy supply while also enhancing food supply through better land management. Nevertheless, as demand for energy grows there is a risk of a repetition of the biofuel story in which competition between food and energy has been widely documented – highlighting the centrality of land- and resource-tenure issues in the sustainability of biomass energy supply. Whatever the outcome, traditional views of an energy ladder that moves away from biomass energy need to be substantially rethought. Comparisons with renewable alternatives in non-OECD countries show that each different energy source has their place, but biomass should certainly be a central component in the renewable energy mix as it is in OECD countries' plans.

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Among renewable alternatives, micro-hydro is among the most cost competitive technologies, but the availability of suitable sites is limited, especially in the light of climate-induced variability in rainfall. Wind power is also highly cost competitive and like micro-hydro is also an attractive source of mechanical power. But wind power suffers from high temporal variability. Solar thermal and photovoltaic technologies have a great deal of potential but suffer from high start-up costs that reduce their cost competitiveness – albeit these costs are on a downward trajectory that some see as a strong argument for further investment in research and development. Although nothing is more available than sunshine, wood fuel and charcoal can effectively be thought of as more accessible and lower cost forms of solar energy.

Traditional demands for biomass such as fuelwood, charcoal and dung for cooking and heating dwelling spaces are predicted to remain high especially in non-OECD countries. Availability can be greatly improved through afforestation, restocking and

more efficient harvesting, conversion, and stove technologies, plus switching to alternative fuels including liquid and gaseous biofuels. Liquid biofuels have been criticised on the grounds of conversion inefficiencies and problems of competition for agricultural land. But both these issues could be addressed through more thoughtful integration of biofuels into agricultural and livestock production and clever use of co-products with careful attention to the rights of local farmers. The much vaunted expectation that second generation ligneous biofuels (yet to see widespread commercial application) will reduce competition for land needs close examination. Marginal / less fertile land needs larger areas to be planted to produce the same amount of energy production, and in many poor countries so-called 'marginal lands' are highly important for green-fallow farming and livestock grazing by the poorest. Less controversially, biogas has been widely promoted. Despite obvious restrictions such as the need for specific operating conditions and the availability of suitable feedstocks and water, in countries such as China 6 million biogas digesters are being installed per year – now well over 30 million in total.

In the area of electricity generation, biomass energy is receiving much new investment in the northern hemisphere, initially with co-generation of heat, but increasingly for stand-alone electricity generation. While such investments are not yet on the scale of investments in conventional liquid biofuels and biogas (such as in India and China), and nor do they have the same geographical spread, they are beginning to be substantial. For example, small-scale biomass electricity plants (in the 5-1000 kW range) that serve off-grid rural communities in countries such as India are proving successful with 1844 such plants installed by 2004. Cost competitiveness can be most readily achieved when a steady operating load can be achieved by linking with local businesses.

Despite such advances, renewable energy programmes in non-OECD countries have tended to restrict their focus on biomass to more efficient, cleaner cooking applications, looking instead to micro-hydro, wind and solar photovoltaic systems for electricity. Biomass certainly does have significant advantages as a heat source. But biomass energy is also highly flexible, capable of meeting many of the diverse rural energy needs: from irrigation pumps and illumination, through agricultural processing and refrigeration to transport and telecommunication. There is a strong justification for a more forward-thinking approach to biomass energy generation in renewable energy programmes. Since much current biomass harvesting is either informal or illegal in non-OECD countries, a crucial first step will be to clarify land tenure and the rights to grow and harvest biomass creating a secure platform for the plantation or management of biomass crops or woodland either on farm or in community areas that encourages formalisation and investment in the growing stock. It will also need: proper extension support and monitoring of the above; the development of standards for the wide variety of potential energy carriers produced, the introduction of fair subsidies for renewable energy technologies; appropriate feed-in tariffs for biomass electricity generation; renewable obligations or quotas to encourage technology diversification; innovative financing mechanisms such as tax credits, rural energy funds and soft loans that include biomass energy; greater investment in research and development; support for energy enterprise development, and local awareness campaigns.

Historic prejudice against biomass energy can readily be tackled by more up-to-date information. But this alone will not be enough to shift towards a more modern approach that harnesses the potential of biomass energy. In many non-OECD countries the scale of the existing biomass energy industry has attracted entrenched vested interests. Charcoal and fuelwood production are often criminalised or captured by politically powerful cartels that profit from the informal land tenure and biomass resource and use rights that prevail in biomass markets, often exacerbated by discretionary law enforcement. Moving towards the formalisation of charcoal and fuelwood supply, based on sustainably managed forest (either natural or planted) requires sustained public pressure backed by solid evidence. But unless the rights and responsibilities of charcoal and fuelwood harvesters, processors and traders are formalised and made sustainable, real prospects for investment in more capital-intensive technologies such as electricity production or second generation biofuels will be undermined.

Inappropriate or unclear government mandates may underlie the lack of momentum towards better use of biomass. For example, control of biomass energy may be spread across forest and / or agriculture departments, energy departments, environmental agencies and so on. It is commonly the case that staff within relevant authorities lack adequate knowledge about the potential of biomass energy and what policies and institutional structures might be appropriate to develop its potential. There is therefore a need to document and spread awareness of how biomass energy could be an integral component of strategies for renewable energy provision and energy security.

This report concludes with a number of policy pointers (primarily for non-OECD country governments) that it is time to take biomass energy seriously. We suggest that biomass energy deserves the following:

- a central place in strategies for national energy security with effective sustainability criteria
- a better understanding of its potential in green economies
- a central role in plans to mitigate and adapt to climate change
- comprehensive data on production and use in national energy statistics and planning
- clear institutional mandates for policy and sector development
- fair treatment alongside other energy sources
- secure biomass tenure based on sustainable management
- incentives for efficient conversion and use
- support for investment in newer biomass technologies
- an active programme of research and development.

We argue that non-OECD governments that take such recommendations seriously may find that biomass development has significant co-benefits for rural employment and poverty reduction, incentives for sustainable forest management, climate change mitigation and adaptation, and last but not least, more secure energy supplies. Most countries have strong energy demands, so the real imperative is to ensure that adequate thought is given towards meeting that demand with a sustainable, efficient supply.

## Introducing biomass energy

This report aims to inform forest and energy decision makers in non-OECD countries of the emerging biomass energy boom and why and how to take advantage of it. The report introduces international trends, summarises the advantages and disadvantages of biomass as an energy source, compares it with renewable alternatives, and concludes with some thoughts on how to develop policy frameworks that optimise its impact on poverty reduction and the preservation of ecosystem services (including climate change mitigation). It draws on a global literature, but with particular attention to Europe (especially the United Kingdom) and Africa (especially Malawi) where the authors have experience in greater depth. The opening section on international trends draws heavily on OECD examples because, notwithstanding rapid developments elsewhere (notably among the BRIC countries – Brazil, Russia, India and China), it is within the OECD itself that biomass energy is receiving of the most attention with the need to reduce fossil-fuel dependency firmly in view. Our intention throughout this report is to stimulate interest in the topic in order to promote serious discussion about how to develop a more sophisticated understanding of, and approach towards, biomass energy in the service of national interests.

**Definitions and scale** – Biomass comprises any organic matter of either plant or animal origin. Biomass energy is the stored solar energy, carbon and hydrogen – captured initially through photosynthesis into chemical bonds – that is now available on demand within that organic matter. It comes in a variety of forms (see Figure 1) although woody biomass accounts for most of this total annual biomass use globally (87 per cent).

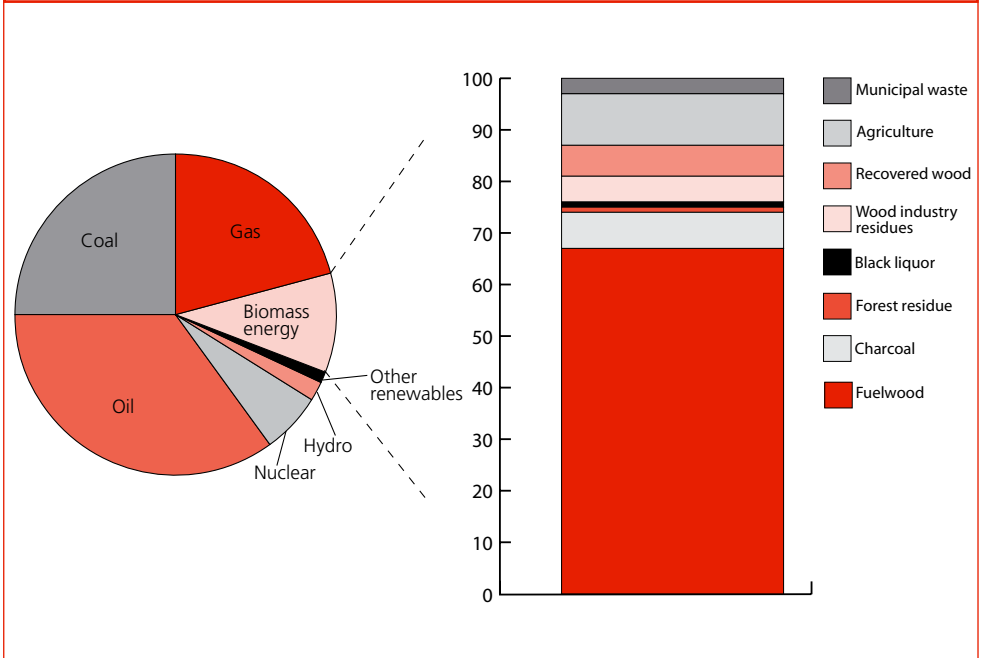
Crude energy is energy that has not been subjected to any conversion or transformation process and primary energy refers to the direct use at the source, or supply to users without transformation, of crude energy. Biomass energy makes up 10 per cent of the total world primary energy mix or 77 per cent of the world primary renewable energy mix.<sup>1</sup>

**Conversion routes** – Energy conversion is a critical issue for biomass energy. Solar radiation provides more energy in one hour to the earth than all of the energy consumed by humans in an entire year. But the efficiency with which plants convert solar radiation into biomass energy is rather low: 100 times less efficient per unit area (though less costly) than solar photovoltaics (Kantha and Leach, 2001). Even the fastest growing crops available only store solar radiation in biomass at a less than 1 W/m<sup>2</sup>, compared with incoming solar radiation of roughly 200–300 W/m<sup>2</sup>, a conversion efficiency of less than 0.5 per cent (Lewis and Nocera, 2006).

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1. The scale of current and future biomass energy supply is considered in more detail in section 3.

**Figure 1.** Current share of sources of primary global energy



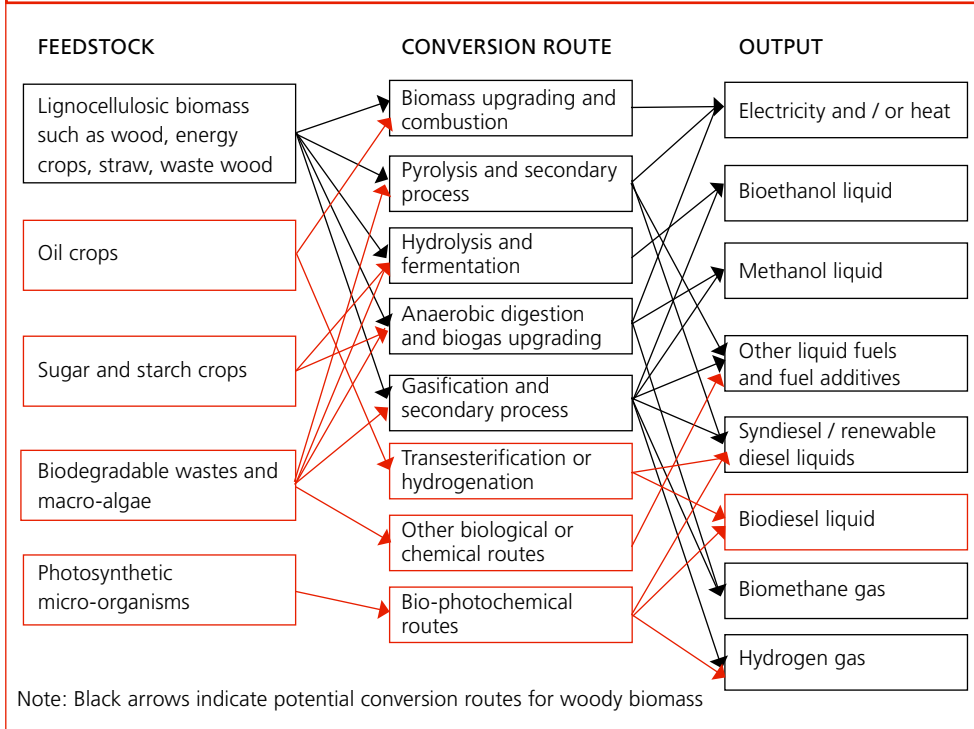
Source: IEA, 2009a

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While a substantial proportion of biomass energy is burnt directly for domestic heat and cooking (for which biomass has substantial comparative advantages over other energy sources), there are now various conversion routes towards all the major energy carriers: heat, electricity, liquid biofuels or gases (see Figure 2). Although such conversion routes are possible to varying degrees this does not necessarily make them sensible from an economic or energy-efficiency point of view, as discussed below.

Chemical transformations turning fuel from one form to another involve either a reduction of the energy value of the material, or the input of energy, or both. Because of this, it is often best from an energy-efficiency perspective to use entire plants in their original form rather than convert them unless the converted form leads to substantial increased efficiency elsewhere. For example burnt wheat grains produce 17MJ/kg but this rises to 28MJ/kg if the wheat stalk is burnt too. If converted to ethanol, the same mass of wheat grains would produce 8.3MJ/kg, a mere 30 per cent of the energy – ignoring the substantial energy inputs needed to achieve the conversion (Ponton, 2009). Of course using the whole plant rather than part of it may have impacts beyond simple energy efficiency, such as the depletion of organic matter in the soil, with potentially serious consequences in areas prone to climate change and drought.

**Figure 2.** Basic biomass energy feedstocks, conversion routes and outputs



Source: IEA, 2009a

If the entire land mass of the United Kingdom were planted with biofuel feedstock it would still only produce less than one-fifth of its current fossil fuel consumption. The use of biomass feedstocks to make liquid biofuel therefore makes little sense. One potential exception is the use of microscopic algae as a feedstock, whose conversion might be more efficient than other plants but is still under commercial development (see Table 1).

A much better option currently is direct co-firing of forest and crop residues and dedicated biomass plantation products for heat, electricity or both. This avoids energy losses in conversion and can substitute liquid fossil fuel currently used for electricity generation, saving it for transport fuels. With electric transport round the corner, electricity generation may soon start to replace liquid fuels in any case.

Gasification is the great future hope as a conversion option for biomass feedstocks, because gas turbines are more efficient at capturing energy than conventional steam turbine options – thus improving the end energy efficiency. The degree to which such options are commercially available or under development is shown in Table 1.

**Table 1.** Status of technology development for biomass energy conversion

Conversion route	Research and development	Demonstration	Early commercial	Commercial
<b>Upgrading</b> (options for making denser more usable feed stocks)	Hydrothermal upgrading (HTU) (use of heat and pressure to convert moist biomass into more usable fuels)	Torrefaction (subjection to milder heat, 200-320°C to improve fuel properties)	Pyrolysis for bio-oils (Chemical decomposition by intense heating above 300°C)	Densification by pelleting or bundling now routine in northern forest residue biomass collection systems
<b>Combustion</b> (options for burning biomass)	Micro fuel cell combined heat and power (domestic)	Organic Rankine cycle engines  Stirling engine combustion		Combustion in sophisticated stoves  Combustion in steam boiler for locomotion, heat and now electricity  Co-combustion with coal widespread
<b>Hydrolysis</b> (options to chemically transform biomass using water)		Lignocellulosic ethanol		Ethanol from sugar and starch crops well developed
<b>Anaerobic digestion</b> (options for using micro-organisms to break down material without oxygen)	Microbial fuel cells	Biobutanol	Biogas upgrading  Two-stage anaerobic digestion  Biogas reforming to hydrogen	Well established biogas use in one-stage landfill gas systems or organic wet wastes such as domestic waste
<b>Gasification</b> (options for using chemical or heat processes to turn biomass into a gas)	Integrated gasification fuel cells  Gasification with reforming to hydrogen	Integrated gasification and combined cycle gas turbine  Syndiesel  Gasification and methanation	Gasification and steam cycle	Gasification for heat production available but total deployment still limited

<b>Transesterification and hydrogenation</b> (options for catalytic conversion of biomass using acids or bases)			Renewable diesel	Biodiesel
<b>Bio-photochemical routes</b> (options for using light and chemical reactions to create biomass)	Biodiesel from microalgae			

Source: Adapted from IEA, 2007a, 2009a

Given the conversion efficiencies and commercial availability of options listed above, the use of forest and crop residues and biomass plantation products directly in heat or electricity production or both is likely to remain competitive in the short- to mid-term. Primary conversion inefficiencies, however, indicate that biomass energy production is likely to be relatively land intensive. In an increasingly land-scarce world this will favour biomass options that are *either* (i) residues or by-products of other forest or agricultural land uses, providing these are not too dispersed or low density or (ii) fast growing perennial crops, which do not require annual energetic land preparation (around 10 per cent of a typical crops' annual gross energy content); adapted to marginal rather than prime agricultural land and requiring minimal energy-intensive fertilisers or (iii) clever cropping arrangements in existing agricultural or livestock management that enhance the productivity of the system (such as agroforestry). Options that solely favour ligneous crops on marginal land may only give an illusion of sustainable development because marginal land will require larger areas of planting to meet the same energy demands as more fertile sites and the poorest people are often disproportionately dependent on green fallows or marginal rangeland for their livelihoods.

**Trends and perceptions** – Biomass energy is the oldest form of energy used by humanity but is often tarred as 'inefficient', 'non-commercial', 'trapping people in poverty' (for example through the drudgery of wood collection eating into other more productive uses of time, or the use of dung reducing soil fertility), 'damaging people's health' or responsible for 'chopping down trees' (World Bank, undated-a). Some analysts have even gone as far as to say that 'the main energy problem affecting poor people in most of the Third World...is their heavy reliance on biomass resources to meet household and agro-industrial needs' (Barnes and Floor, 1999). If not tackled, such problems particularly affect women and children as the burden of wood collecting falls on them and smoke inhalation from cooking on inefficient stoves is primarily a domestic issue (Clancy *et al.*, 2002). As a result, some major development organisations have ignored biomass energy altogether (World Bank, 2003;



UNDP, 2002). Some of these accusations against biomass energy may be true when it is inappropriately managed and used (especially in domestic settings), but the same could be said for the inappropriate management and use of most alternative energy sources (Torres-Duque *et al.*, 2008).

Growing understanding of how to solve such problems, such as more efficient stoves, better ventilation and smoke extraction (Barnes *et al.*, 1994), combined with recent technological advances (for example in harvesting, densification or conversion to more usable fuels), make the continued rejection of biomass energy seriously outdated. State of the art programmes to reach national carbon neutrality in Denmark by 2050 have a doubling of biomass resource use as a central component (Lund, 2007; Lund and Mathiesen, 2008). Underpinning these ambitious plans are increasing co-firing, combined heat and power options, incentives to switch key agricultural grain crops towards those that produce greater volumes of residual biomass after harvest (for example, switching from wheat to corn results in no loss of food but produces much greater biomass energy feedstock outputs). The latest World Energy Outlook strongly suggests increases in the commercial use of biomass energy (IEA, 2009b).

As biomass energy begins to take on an expanding role in the energy security of countries on the north, research and technological developments have gathered pace. One emphasis has been on using agricultural and forest residues efficiently.

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Photo: Mike Goldwater

**Western Wood Energy Plant at Port Talbot, Wales, generating 14 MW by burning 500 tons daily of wood and residues**

For example, when harvesting forest biomass residues after logging, research has shown the profitability of processing logging residues using new bundling technology rather than localised or remote pelleting systems. The most important factors in the overall reduction in CO<sub>2</sub> emissions were the type of biomass energy installed versus fossil fuel replaced and the net amount of biomass harvested per unit area – not transport costs as might have been supposed (Eriksson, 2008).

At the domestic level, biomass combustion is also advancing. Wood fired heating systems are increasingly used across Europe, often with more flexible pellet fuel rather than larger logs or woody bundles. For example, in Austria 80 per cent of new homes are equipped with wood pellet boilers as standard, some with fully automated ‘fit and forget’ feed systems. Bags of wood pellets are available from local shops. A typical house requires a 25kW boiler and a 6 tonne, 3m x 3m wood pellet store (Hartman, 2009). The advantage of wood fuel heating is that despite its high initial installation costs, running costs are low (Ashden Awards, 2009). This means that wood fuel systems are particularly suited to supplying high and steady levels of energy (often found in communal or industrial rather than domestic settings – see examples in Korhaliller, 2010).

But combustion for heat is only one option. Increasingly woody biomass is also used for both combined heat and electricity generation. There are already advanced fluid bed technologies that give high combustion efficiencies, low running costs and high flexibility, mostly at larger scales (20-100MW). Using the United Kingdom as one OECD example, approximately 1 million tonnes of biomass are currently burnt or co-fired in dedicated biomass power stations. Some 3GW of ‘large’ biomass power projects (>350MW) have received planning permission and are in development requiring 20-25 million tonnes of biomass every year. In addition, 4GW of medium and small biomass power projects (100-350 MW) have received planning permission and are in development requiring 30-35 million tonnes of biomass every year. In total over 7GW of biomass power plant is currently being developed requiring 50-60 million tonnes of biomass every year (Bonsall, 2010). This equates to 5-6 times the available biomass of the entire British Isles, estimated at 10 million tonnes, although the exact total is highly dependent on complex existing markets for agricultural and forest crops and residues. Despite the relative abundance of timber supply elsewhere in Europe, it is still estimated that by 2020 there will be a biomass deficit of roughly 200-260 million cubic metres of wood (roughly equivalent to 100-210 million tonnes) in 16 countries surveyed (CEPI, 2007).

Even at the domestic scale, systems are now available that generate both heat and electricity from woody biomass albeit with quite stringent fuel quality demands (such as quality graded pellets). Commercial gasification technology is also at commercial stage but with limited deployment due to high initial costs and demanding operational requirements and fuel specification (IEA, 2007a).



Photo: Mike Goldwater

A brush baler at work to supply a biomass power station at Port Talbot, Wales

## Scale of current and projected future biomass resource use

New technological options (described above) introduce new possibilities both for current biomass resource use and future projections. Both in the north and the south this means the potential of biomass as a renewable energy source has to be continuously reassessed.

The current world annual consumption of primary energy is about 500 EJ,<sup>2</sup> projected to rise to between 600-1000 EJ by 2050 (IEA, 2009a). Globally, biomass energy supplies some 50 EJ or 10 per cent of that total (although under-reporting of domestic use may mean this figure is closer to 13 per cent) (Openshaw, 2008). Biomass energy represents about 3 per cent of the primary energy mix in OECD countries and 22 per cent in non-OECD countries (see Figures 3 and 4). Woody biomass accounts for most of this total annual biomass use (87 per cent).

Perhaps surprisingly, *per capita* use of woody biomass is roughly equivalent between rich and poor countries. For example with 18 per cent of the global population, OECD countries account for 17 per cent of the total use of woody biomass. This contrasts sharply with a much higher per capita use of nuclear, and solar and hydro renewables in OECD countries and a very much higher per capita use of non-renewable fossil fuels.

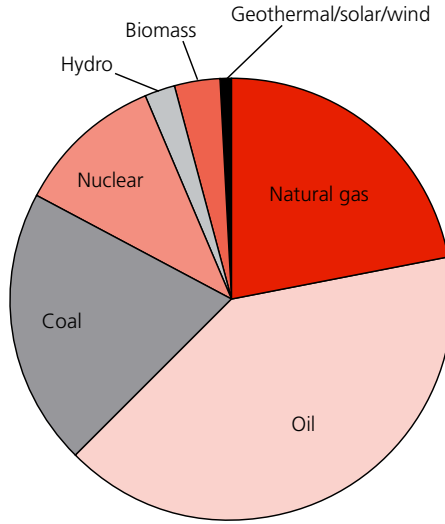
Total per capita use of energy in 2005 was 198 gigajoules in OECD countries, compared with 47 GJ in non-OECD countries against a global average of 75GJ. But it is non-OECD countries that are particularly dependent on biomass energy (Figures 3 and 4). As noted above, this used to be seen as 'backward' but could now be regarded as a head start in moving 'forward' towards renewable commercial energy sources that are climate friendly.

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2. 1 EJ = 1 exajoule =  $10^{18}$  joules = 24 million tonnes of oil equivalent

**Figure 3.** Energy consumption in the OECD by source, 2005

Out of total 2005 energy consumption of 231.6 EJ by 1.17 billion people (198 GJ per capita)

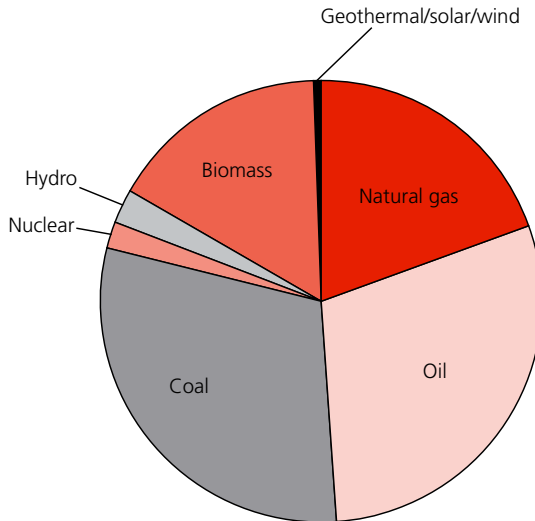


Source: Openshaw, 2008

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**Figure 4.** Energy consumption in non-OECD countries by source, 2005

Out of total 2005 energy consumption of 246.8 EJ by 5.26 billion people (47 GJ per capita)

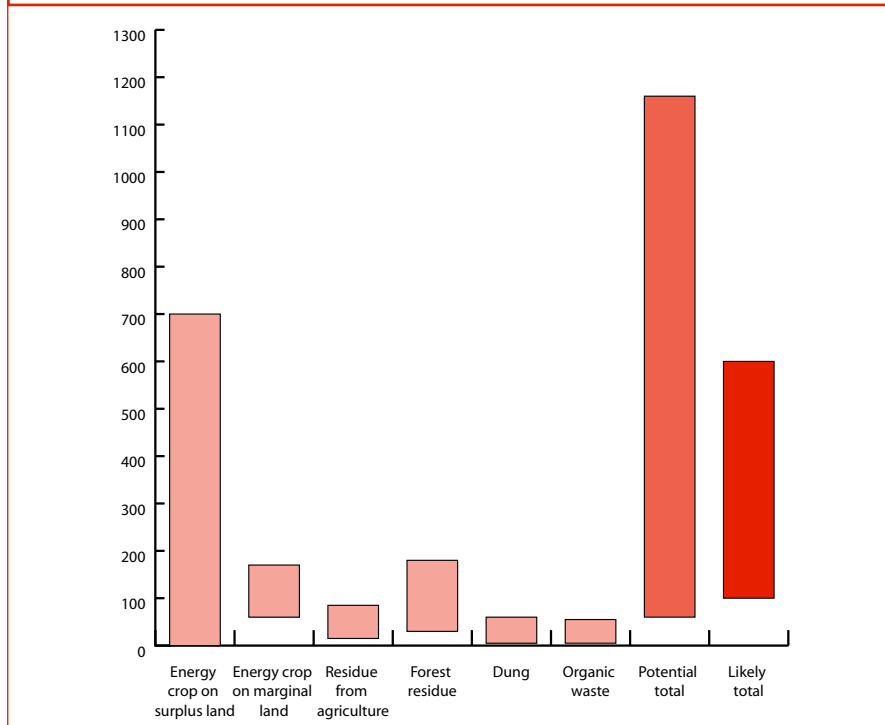


Source: Openshaw, 2008

Future contributions of biomass to global energy supplies may greatly exceed current contributions. After respiration, plants sequester through photosynthesis roughly 50 billion tonnes of carbon per year as biomass. Humans only use 1.2 billion tonnes of this biomass to generate approximately 50 EJ of energy, allowing 48.8 billion tonnes of carbon to return to the atmosphere through decomposition without capturing its energy for productive use. This represents an energy source equivalent to 8 times total current fossil fuel use (Openshaw, 2009). Of course not all of this decomposing biomass could be converted into energy. The availability, yield and processing logistics of different energy crops and residues across evolving natural, human and political landscapes will vary and is complex to model. In a review of 17 estimates, the likely contribution of biomass to future energy supply ranges from below 100 EJ/yr to above 400 EJ/yr (Berndes *et al.*, 2003). More recent estimates have even hinted at upper sustainable limits of 500 EJ/yr with biomass likely to meet up to a third of total projected world primary energy consumption in 2050 (IEA, 2009a).

The future supply of biomass energy is projected to come primarily from woody crops, both herbaceous perennials and woody species (a major part of the left hand column in Figure 5). Adding together all possible sources of supply gives

**Figure 5.** Potential ranges of future land based biomass supply by 2050 (EJ per year)



Source: IEA, 2007a



the potential total supply, but for a number of reasons the actual future supply is likely to be less than this potential total. For example, land availability for biomass is particularly affected by agricultural productivity. If more land is needed for agriculture, less is available for energy crops, and agricultural and forest residues become that much more important in future projections of supply. But here too there are competing demands and models therefore show a much more realistic likely total (which nevertheless still greatly exceeds current biomass supply for energy use). It is widely predicted that the overall trend of rapid market expansion is likely to continue with growing international trade in both solid biomass and liquid biofuels (see Figure 6).



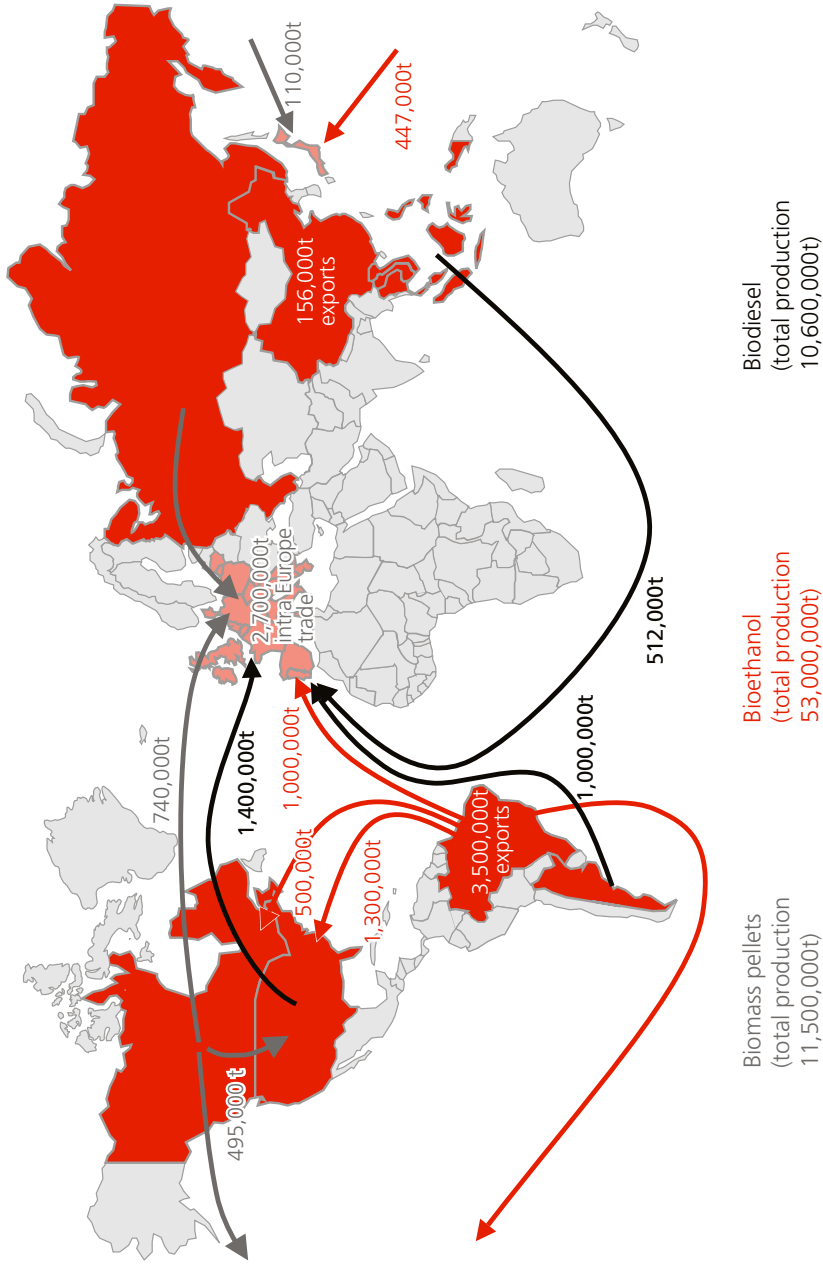
Photo: Mike Goldwater

12

**Louise Simmons of TV Energy in a new willow coppice plantation that supplies Slough Heat and Power Station, UK**

In 2009 world biofuel production surpassed 100 billion litres with a significant international trade involving both OECD and non-OECD countries (S&T<sup>2</sup> Consultants, 2009). Brazil is the major exporter of bioethanol, whereas the United States, Argentina, Indonesia and Malaysia dominate the exports for biodiesel. Europe and North America dominate the wood pellet trade. By 2009 pellet production in Europe stood at 8.3 million tonnes (Junginger *et al.*, 2010) with Sweden leading production and leading consumers such as Italy having installed 800,000 pellet stoves. The North American market in 2008 involved production by the United States of 1.8 million tonnes with a considerable trade to the United States from Canada, which produced 1.3 million tonnes in 2008, rising to 1.4 million tonnes in 2009 (Egger and Öhlinger, 2009; Junginger *et al.*, 2010).

**Figure 6.** Estimated flows in the international trade in biomass energy, 2008



Source: Adapted from Junginger et al., 2010





Photo: Mike Goldwater

**Miscanthus growing at Rothamstead Research Centre, a perennial grass which combines the fast growth rate of a tropical grass with a tolerance to grow at UK temperatures**

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Growing demand is being driven in different countries by a mix of concerns over energy security, rural development, export development and climate change mitigation (Dufey *et al.*, 2007). Dominance by particular drivers may have an impact in other areas. For example, the concerns of OECD country citizens and governments over energy security and climate change mitigation have led to targets on liquid biofuels, heat and electric power generation. For example, the EU has set a binding target of 10 per cent for biofuel in transport fuels by 2020, part of a 20 per cent target for renewable energy within the EU energy mix by 2020. In the United States, the Senate has suggested a production target of 136.3 billion litres of renewable and alternative fuels per year of which no more than 56.7 billion litres could come from corn-based ethanol (Murphy, 2007). These targets have led to a massive international investment boom in biofuels that so far exceeds investment in biomass electricity production (a more recent boom). There have been serious concerns over trade-offs such as competition for agricultural land and the resultant increases in world food prices. As a result, strategic decision trees have been developed to help policymakers assess the potential trade-offs (Vermeulen *et al.*, 2008).

## Advantages of biomass energy for non-OECD countries

Biomass energy has a number of significant advantages for non-OECD countries where energy access, balance of payments, poverty reduction and ecosystem service provision (including climate change mitigation and adaptation) are important objectives. When compared with other energy sources (and especially fossil fuels) these advantages should make political support for expanded and more sophisticated use of biomass energy a no-brainer (Kartha and Leach, 2001):

**Local accessibility / localised economies** – Biomass feedstocks are more widely accessible than fossil fuels and most other renewable energy sources especially in areas beyond the reach of electricity grids or road networks. For simple uses they do not require complex technology for extraction or processing (such as drills, turbines or solar panels) although more advanced biomass energy systems do require considerable technological investment. It is little wonder that over 2 billion people use biomass every day to cook. Figure 7 and Table 2 show estimates of the national proportion of households dependent on solid biomass fuels. There is clearly a particularly high biomass dependency in sub-Saharan Africa and South Asia.

There is an immediate and rather striking correlation between domestic biomass dependence and poverty which has always been interpreted to mean that biomass energy is symptomatic of poverty. However, as OECD policymakers scramble to climate-proof their economies and secure future

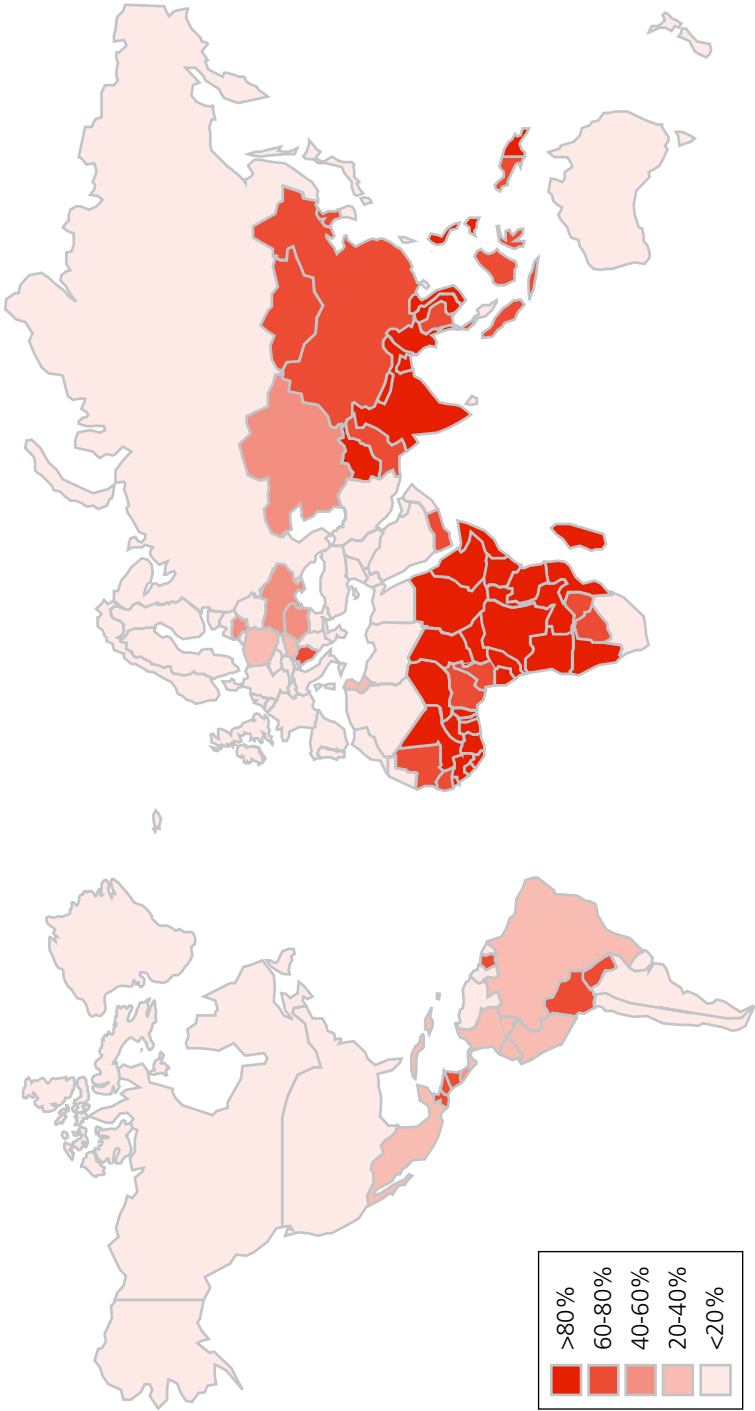


Photo: Mike Goldwater

**A group of charcoal producers cutting cashew nut trees in Nampula, Mozambique**

energy supplies, this thinking is being turned on its head. Perhaps dependence on locally available, renewable, carbon neutral energy feedstocks is not such a poor idea after all. The massive recent investment in biomass power generation in OECD countries is testament to this about-turn. New thinking on 'greening the economy' or 'decarbonisation' has biomass energy firmly in view (Worldwatch Institute, 2007; Shinnar and Citro, 2007).

**Figure 7.** Estimated national fractions of households dependent on solid biomass fuels



Source: Smith et al., 2004

**Table 2.** Population dependent on biomass in the developing world in 2002

Region	Population using biomass (millions)	Percentage share of total population
East Asia (including China)	998	54
South Asia (including India)	711	54
Latin America	96	23
North Africa / Middle East	8	0.05
Sub-Saharan Africa	575	89
Developing countries	2,385	52

Source: OECD and IEA, 2002

**Ecological sustainability / energy security** – Biomass grows, and provided extraction techniques do not exceed the regenerative capacity of soils and ecosystems, biomass energy systems can be indefinitely renewable, unlike fossil fuels. Yet, turning ‘potential’ sustainability into ‘actual’ sustainability requires detailed ecological understanding of the management of both natural and plantation biomass resources, not to mention all the complexities of good governance. There are particular concerns over the sustainability of plantations based on biodiversity loss in any conversion from natural forests and the perception that continual removal of biomass will eventually lead to nutrient depletion in soils. The issue of natural forest conversion is common for all agricultural crops (of which we consider forest plantations to form a part) The advantage of biomass crops is that they may be more adaptable to marginal or degraded lands or may be harvested as residues from existing agricultural or forest land. To prevent nutrient depletion, forest biomass harvesting can leave sufficient stems, leaves and tops behind to conserve organic matter and nutrients. If nutrients are returned to the site from ash recycling once per rotation this compensates for most losses. Annual crops place higher demands on nutrient levels but these can be maintained by standard agricultural or silvicultural practices (Simpson *et al.*, 2006).

In order to verify that biomass feedstocks are indeed produced sustainably, various certification systems are under development to provide assurances to the market. Sustainability certification has emerged in several sectors relevant to biomass. For example, forest certification systems such as the Forest Stewardship Council (FSC) and the Programme for the Endorsement of Forest Certification (PEFC) are more than a decade old. There are also agricultural equivalents such as the Sustainable Agriculture Network (SAN) and the EurepGAP (European Good Agricultural Practices) systems. Green electricity certification schemes have also been developed such as EUGENE, Milieukeur, OK-power, Green Power and the Austrian Ecolabel (van Dam *et al.*, 2006). While there are no binding sustainability criteria for biomass in the EU yet, the European Commission has recommended that member states integrate voluntary biomass sustainability criteria into their own national schemes. The Commission will then report back on the

sustainability measures taken by national schemes by the end of 2011. Minimum criteria for biomass sustainability may then be set by the European Committee for Standardisation (CEN) which would define minimum requirements and allow competitive development of certification standards (BTG, 2008). Energy ministers from several member states (the Benelux countries, the United Kingdom and Poland) have already called on the Commission to introduce a harmonised system of legally binding sustainability criteria for biomass production for heating and electricity (Prakesh, 2010). If such criteria were to be set there will still be a time lag before implementation – and potentially some gaps that will require redress over time – but long-term guarantees of sustainability are likely to emerge.

**Carbon neutrality/decarbonised economies** – The simple equation balancing carbon uptake during biomass growth and carbon release during combustion or conversion must be approached with caution. If emission reductions are required immediately, and standing forests (rather than new energy crops) are being felled for biomass, there is an upfront carbon debt (the immediate release of carbon upon burning) which will only be repaid after a substantial time frame as the trees grow and sequester carbon from the atmosphere (Zanchi *et al.*, 2010). As demand for biomass energy grows there will be a general decrease in the amount of wood left on the ground, and in numbers of over-mature standing trees, which will further exacerbate this short-term carbon debt. So while it is true that in a stable and sustainable forest landscape, over its entire life cycle, the use of biomass will substantially reduce emissions in comparison with fossil fuels, for forest crops the time frames to achieve this are long (longer perhaps than short-term emissions reduction targets). For example, one recent study calculates that it may take between 21 and 90 years before biomass electricity pays off this carbon debt and has a global warming advantage over coal and natural gas electricity power stations respectively (Manomet, 2010).

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In addition, inefficient burning of biomass can produce products of incomplete combustion (PICs) which can have much greater impact on global warming than CO<sub>2</sub>. Experiments have shown that, for situations of sustainable harvesting where CO<sub>2</sub> emissions are considered neutral, some improved solid-fuel stoves with high temperature combustion and ventilation assistance can reduce the overall warming impact from PICs by as much as 50-95 per cent. Charcoal burning may emit less CO<sub>2</sub> than traditional wood burning, but the PIC emissions are significantly greater (MacCarty *et al.*, 2008).

These details are important because, depending on the time horizons involved and the extent of PICs produced, the global warming impact of something like a meal cooked on a biomass stove can actually exceed that of one cooked using fossil fuels, even if based on renewably harvested fuel. Nevertheless, if long time horizons are used and adequate attention given to biomass conversion efficiency, large savings can be made against conventional fossil fuels. In particular, gasification and the burning of liquid biofuels with high efficiency in simple devices, have a low impact on global warming. A detailed life-cycle analysis was

made of a biomass gasifier electricity plant fuelled from a eucalyptus plantation supplying a hospital and shop in Amuru district of Uganda (Amezaga *et al.*, 2010). When the plantation productivity was low (5 oven-dry tonnes/ha/yr) the gasification system produced 51 per cent of the greenhouse gas (GHG) emissions of the fossil fuel equivalent. But with a higher plantation productivity (15 oven-dry tonnes/ha/yr) the biomass system produced only one-third of the emissions of the fossil fuel equivalent – a function of lower harvesting and transport emissions. Such examples highlight the advantage that upgraded fuels made from biomass might have in moving toward sustainable energy futures (Smith *et al.*, 2000). For example, the global production of 100 billion litres of biofuel displaces 1.15 million barrels of crude oil per day, a saving of approximately 215 million tonnes of GHG emissions annually (S&T<sup>2</sup> Consultants, 2009).

**Production flexibility** – There is already technology commercially available to convert biomass into all of the major energy carriers (heat, electricity, liquid biofuel and biogas). Biomass can therefore be adapted locally to various uses from traditional cooking and cleaner and more efficient stoves, to smokeless liquid and gaseous fuels or electricity generation. Local supplies of biomass can be used viably in places where centralised supply networks fail to reach.

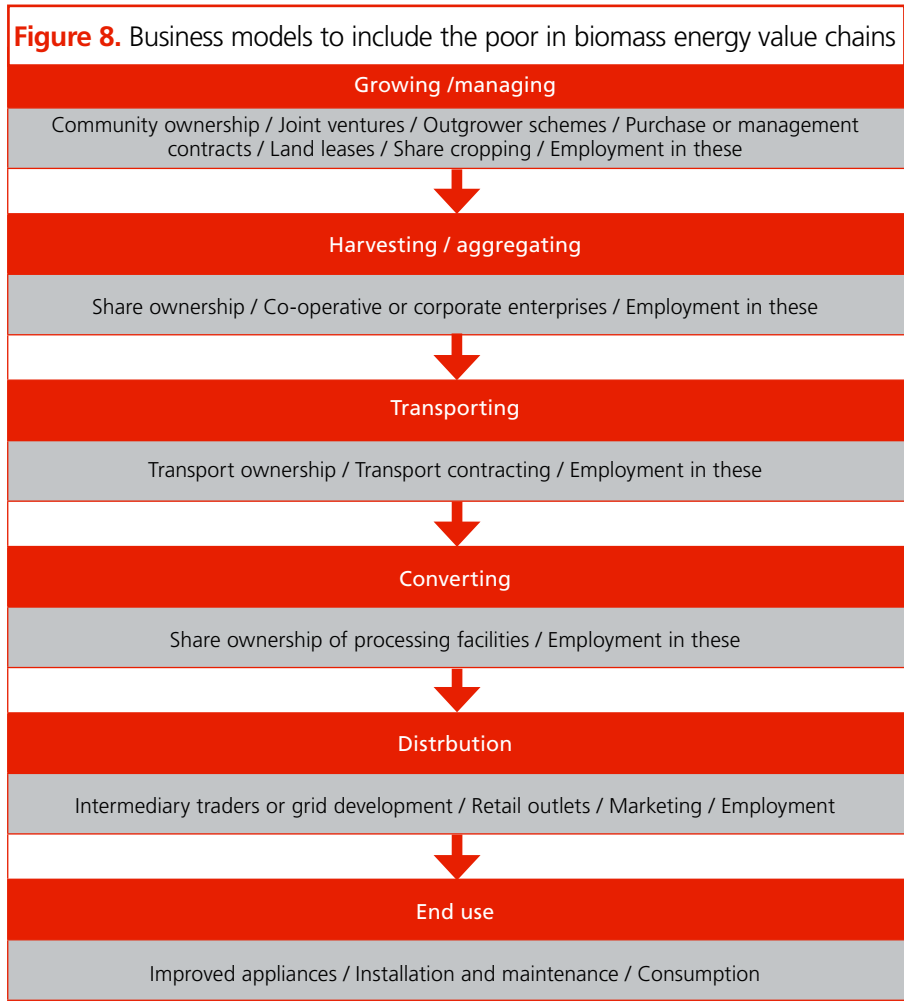
Biomass energy also comes ‘pre-stored’ in readily available feedstocks with substantial shelf lives. They usually require no expensive storage solutions such as batteries, are not intermittent like solar energy, wind and wave power, and do not suffer from external factors such as siltation in hydropower systems. Nevertheless, biomass feedstocks must be stored carefully, as inappropriate temperatures or humidity levels can result in decomposition or composting which can lower the energy content. Provided this is precaution is taken, they may be drawn on whenever the need arises.

The high initial investment costs but lower running costs associated with more advanced combined heat and power systems do have implications for the ideal scale of biomass power plant. More advanced biomass energy systems are economically favoured by steady maximum-output consumption of the resultant energy, which is more likely among communal or industrial users than domestic ones. So for these advanced systems, while biomass energy may be drawn on as required, it is often economically advantageous to make sure this demand is steady and high. In practice this can mean targeting these technologies at those rural areas where there is a steady demand from industry of some kind rather than installing them where there is only domestic demand.

**Labour intensity / green jobs for poverty reduction** – Value chains based on biomass involve a range of activities and can therefore generate employment. Biomass requires cultivation or collection from the wild. It must be aggregated, densified or milled and refined. It must be transported and converted into heat, electricity, gas or liquid. It may be redistributed and sold on. For many of these stages in the value chain there may be opportunities to deliberately involve the

poor (Figure 8) Even simple biomass energy chains, such as the production of charcoal for domestic use, can generate considerable employment.

For example, in Malawi, one of the few national surveys of charcoal production and use found that 92,800 people owed their livelihoods to charcoal. This included 46,500 producers, 12,500 bicycle transporters, 300 other transporters and 33,500 traders (Kambewa *et al.*, 2007). Further research in 2008 that included fuelwood led to a revised total figure of 133,000 full time people employed in wood fuel value chains. By contrast fewer than 5000 people were involved in the supply chains of other fuels (Openshaw, in press). If Malawi's figures are applied to current estimates of wood energy consumption in sub-Saharan Africa then approximately 13 million people are employed in commercial biomass energy in sub-Saharan Africa alone.



Source: Adapted from Vermeulen *et al.*, 2009

The labour intensity of biomass energy production is also hinted at more globally. In an overview of employment estimates in the renewable energy sector, the employment in biomass greatly exceeded other renewable sources (Table 3) although this may be a function of the greater extent of biomass use.

Other studies comparing employment per unit of energy produced have been more useful in quantifying the labour intensity of biomass energy. In general these have found that all renewables produce more employment per unit energy than fossil fuel alternatives (Wei *et al.*, 2010). Wind and solar have the highest employment multipliers but these figures only compare jobs in construction, installation, management, operation, maintenance, fuel extraction and processing (see Figure 9). They do not appear to include fuel production and harvesting which is likely to be a major employer in biomass energy sectors.

**Table 3.** Employment estimates in the renewable energy sector for countries where information was available in 2006 in full time job equivalents

Renewable energy source	World (minimum estimate based on data available)	Selected countries	Employment estimate from selected countries
Wind	300,000+	Germany	82,100
		USA	36,800
		Spain	35,000
		China	22,200
		Denmark	21,000
		India	10,000
Solar Photovoltaic	170,000+	China	55,000
		Germany	35,000
		Spain	26,449
		USA	15,700
Solar Thermal	624,000+	China	600,000
		Germany	13,300
		Spain	9,142
		USA	1,900
Biomass	1,174,000	Brazil	500,000
		USA	312,200
		China	266,000
		Germany	95,400
		Spain	10,349
Hydropower	39,000+	Europe	20,000
		USA	19,000
Geothermal	25,000	USA	21,000
		Germany	4,200
<b>Combined total</b>	<b>2,332,000+</b>		<b>2,277,000</b>

Source: UNEP, 2008



**Figure 9.** Average and range of job years per GWh of energy produced for ten different energy technologies.

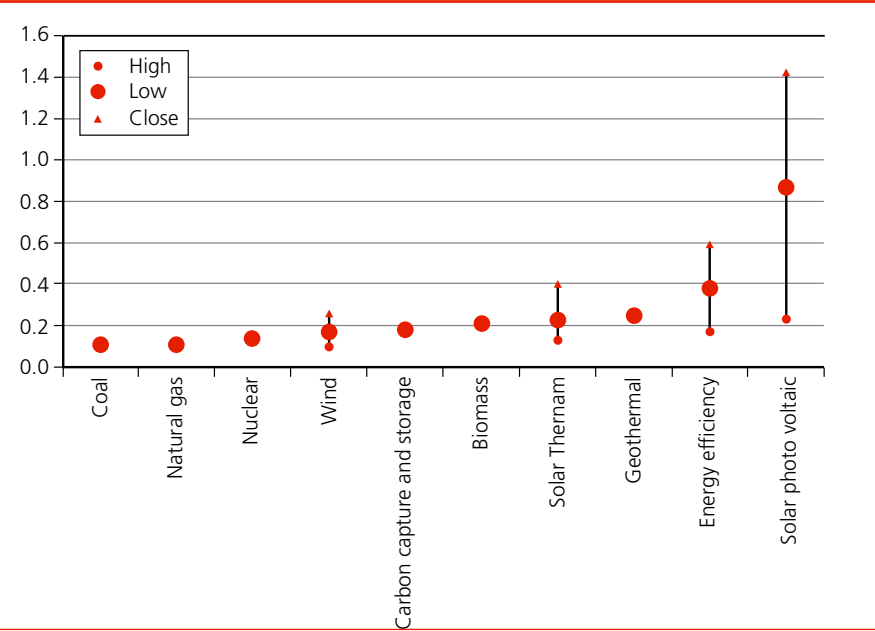
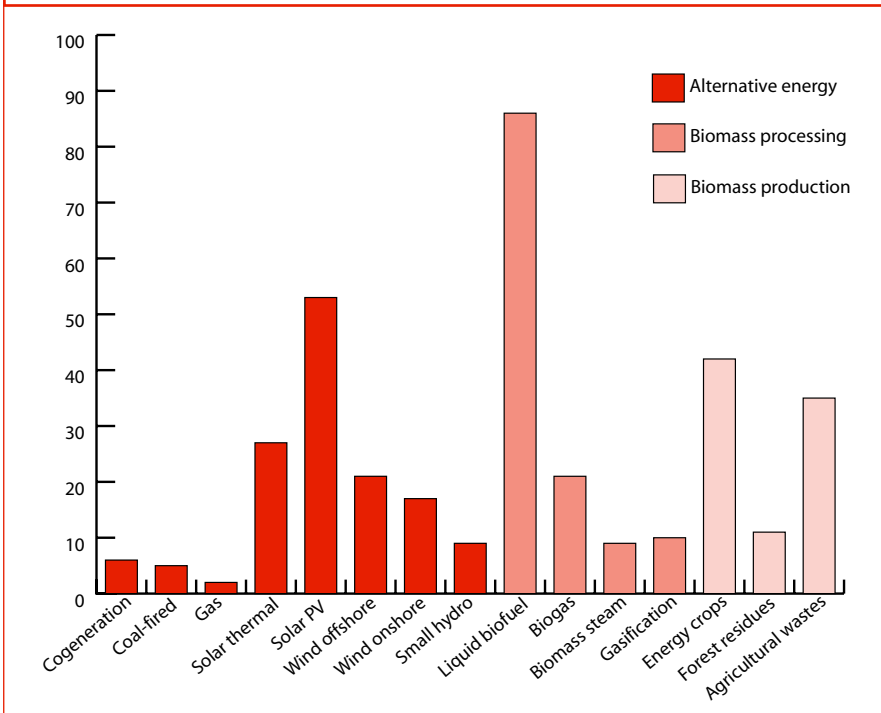


Photo: Mike Goldwater

**One of thousands of bicycle transporters earning their living from fuel wood in Mozambique**

When one includes the jobs created in the production and harvesting of the biomass energy crop, the advantages of biomass energy become more apparent (Figure 10). Nevertheless, although employment opportunities from greater bioenergy uptake are often quoted, finding willing workers for what can be somewhat arduous and repetitive work may not be easy in either developed or developing countries (IEA, 2007b).

**Figure 10.** Employment requirements for energy projects – operating and maintaining jobs / 100GW

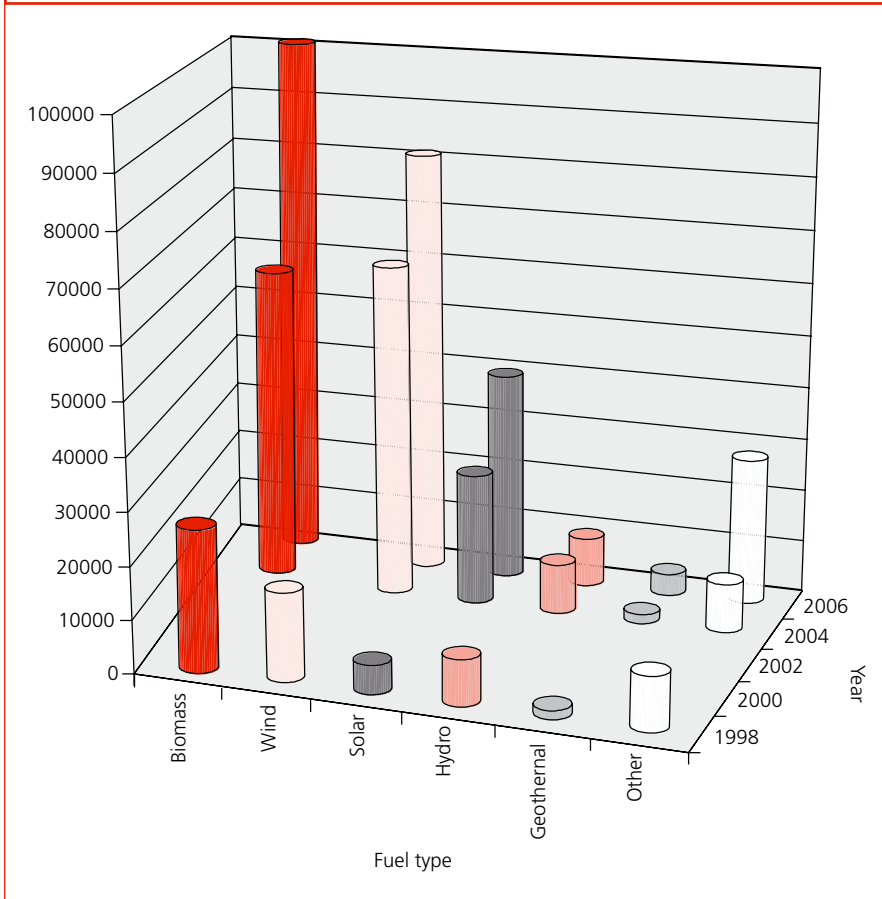


Source: IEA, 2007b

Germany is one of the world's leading renewable energy nations and now has more than 20,000 companies in the renewable sector (many of them small and medium in size). Of these, 10,000 are in solar energy, 5000 in biomass energy, 3500 in wind power and 500 in geothermal. Between 1998 and 2006 employment in all renewables had risen from 66,600 to 259,000 jobs. By 2020 this is predicted to rise to 400,000 and by 2030 to 710,000. Figure 11 shows a more detailed breakdown of German renewable employment figures and the rise of biomass employment.

Whether in Germany or non-OECD countries, an attractive feature of biomass energy value chains from a poverty reduction standpoint is the number of opportunities for the poor to be involved. There are also a number of simple ways

**Figure 11.** Employment in the German renewable sector – full time job equivalents



Source: Worldwatch Institute, 2007

in which policymakers can encourage their inclusion such as land tenure security, subsidised finance and insurance schemes, fiscal incentives such as tax breaks, local supply quotas, and active support in the form of information, training and research (Vermeulen *et al.*, 2009).

It might have been expected that some or all of these advantages of biomass energy might have translated into major investment in this sub-sector, especially for countries where energy accessibility, balance of payments deficits and poverty reduction are key considerations. That this has not routinely happened requires a more detailed look at the preferences within current renewable energy programmes designed for non-OECD countries and the costs and benefits they ascribe to different renewable options. This will be done in Chapters 4 and 5.

## Renewable energy alternatives in non-OECD countries

Around 1.6 billion people in non-OECD countries lack access to electricity. Some 2.4 billion use inefficient forms of biomass as primary cooking and heating fuels. Poor people are already spending money on energy services, but not necessarily getting most efficient, healthiest or cleanest returns for their money (Wilson and Zarsky, 2009). The energy services they are paying for include lighting, heating for cooking and space heating, power for transport, water pumping, grinding, and numerous other services that fuels, electricity, and mechanical power make possible (Modi *et al.*, 2005; Hofmann *et al.*, 2009; TERI, 2008; GNESD, 2007; Cherni *et al.*, 2005). It is now widely recognised that the Millennium Development Goals (MDGs) cannot be achieved without basic levels of access to energy (Hofmann *et al.*, 2009; REN21, 2005a).

There is also a growing realisation that unless energy needs can be met in sustainable ways, catastrophic climate change will result, with the poorest groups hit hardest and fastest. As a consequence, renewable energy has received increasing attention in both north and south albeit it against quite different backdrops.

Despite recent changes in emphasis, historic energy development patterns in most countries have focused primarily on conventional petroleum-based energy sources and centralised grids (REN21, 2005a). Although evidence suggests that this energy path has so far failed to meet the energy needs of the poor, it is nevertheless still pursued by many governments (GNESD, 2007; Khennas and Barnett, 2000b). For example, China's energy path has been very coal intensive, but in 2006 4.6 million households still did not have an electricity supply and were unlikely to get one in the next two decades (GNESD, 2006).

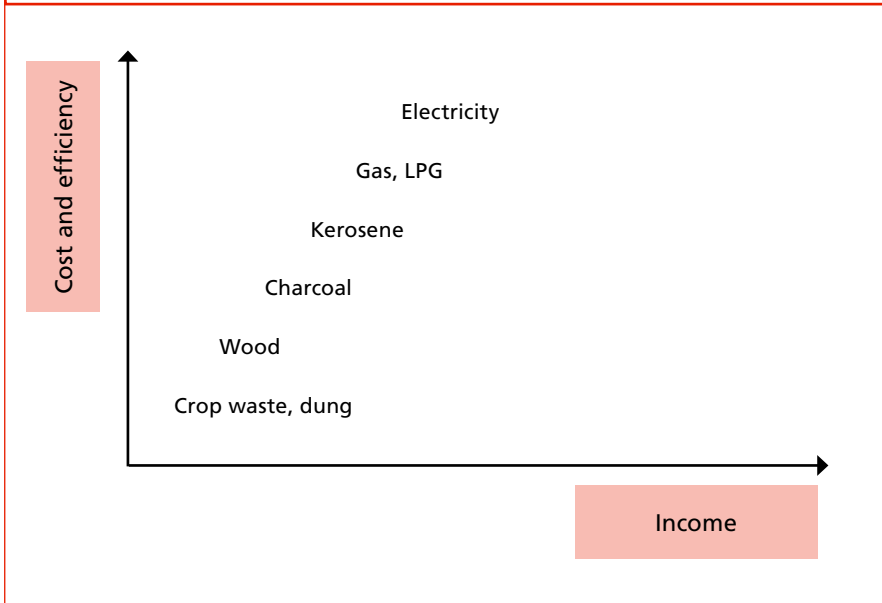
Energy poverty is a growing concern and is defined by the United Nations Development Programme (UNDP) as:

*'the absence of sufficient choice in accessing adequate, affordable, reliable, quality, safe and environmentally benign energy services to support economic and human development.'* (UNDP, 2000; p. 508)

While limited 'access' to energy is certainly a factor of energy poverty, a more robust definition might also include the lack of opportunities involved in energy supply.

According to the UNDP, key barriers to accessing energy are physical access and affordability (Giri *et al.*, 2004). But barriers to participating in supplying energy extend to a lack of entrepreneurial and technical skills and constraints to market development.

**Figure 12.** Outdated energy ladder concept



Source: IEF, 2009

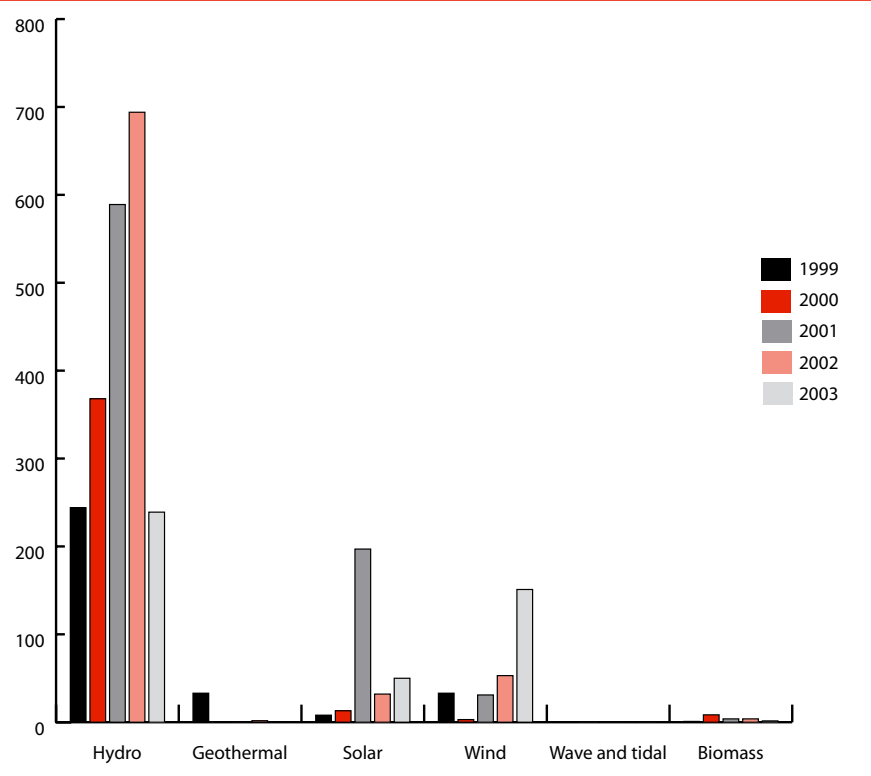
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As mentioned earlier, the current discourse on energy poverty frequently differentiates between 'modern' and 'traditional' fuels and a very negative perception of the latter has grown up among development practitioners, energy suppliers and users. 'Modern' fuels are considered to be kerosene, gas, liquefied petroleum gas (LPG), or electricity generating technologies and 'traditional' fuels such as firewood or agricultural waste often end up at the bottom of the energy ladder (Figure 12).

Consequently, efforts have been mostly directed making 'modern' energy sources accessible in an attempt to climb the energy ladder and move away from 'traditional' fuels. The literature commonly uses the figure of 3 billion people worldwide currently deprived of 'modern' fuels, but much of this population do have access to energy (Practical Action, 2009a). As interest has turned towards renewable energy this historic pattern has continued, with biomass being overlooked despite its renewable credentials. Figure 13 shows how the distribution of overseas development assistance (ODA) into renewable alternatives reflects such perceptions.

With more and more examples of energy sources such as fuelwood and agricultural waste being used as highly efficient renewable energy sources, we need to rethink this simplified differentiation between what is 'modern' and what is 'traditional'.

**Figure 13.** Overseas development assistance for renewable energy, 1999–2003 in US\$ million



Source: UNEP, 2008

In the following sections we review the renewable energy technologies that have been promoted in non-OECD countries at a local level and outline the successes and failures and barriers that remain to be overcome. We have opted to ignore the large-scale hydropower investments that have dominated ODA in renewable energy because we felt their scale, infrastructure requirements, financial inputs and potential impacts were a subject in their own right and beyond the scope of this study to explore.

Instead we have focused on renewable energy technologies that use locally available renewable resources such as the sun, wind and water to generate electricity, mechanical power or in the case of biomass, a fuel in the form of a solid, liquid or gas. They can supply both on- and off-grid energy and are important in diversifying energy supplies (Olz *et al.*, 2007).

**Micro-hydropower** – Among the most cost competitive forms of renewable energy is micro-hydropower (see cost comparisons in Chapter 5). Micro-hydropower uses small-scale local water channels to generate a renewable source

of energy (Practical Action, 2006b). The exact range of micro-hydro plants varies in the literature but is generally between 10kW-200kW (Khennas and Barnett, 2000a). They are interesting to development practitioners because they cause minimal flooding and community displacement, in contrast to large hydropower projects (Practical Action, 2010). Micro-hydropower is said to have a strong potential for poverty reduction, 'in terms of costs per person moved across the poverty line' (Fulford *et al.*, 1999, cited in Khennas and Barnett, 2000b, pg 6; Practical Action, 2006b).

Micro-hydropower is expanding fairly rapidly in developing countries. Compared to other small-scale decentralised energy systems, it is said (by proponents) to:

- be the most technologically mature (Khennas and Barnett, 2000b)
- be simple to maintain with low energy costs (EREC, undated, cited in REN21, 2005a)
- have an operating life of at least 20 years (Practical Action, 2010)
- have a high potential for local manufacture, contributing to significant cost savings (Indian MNES, undated, cited in REN21, 2005a).

Unlike solar photovoltaic (PV) and wind power, which have problems of intermittency, micro-hydro plants can generate power continuously (except where water resources themselves are seasonally intermittent or entirely absent in very arid regions). Additionally, community members can become involved in the supply of this energy source, either via construction of the plant or through continuous operation and maintenance.

Micro-hydropower has been widely used in China and Indonesia. In China, micro-hydropower is a mature industry which has been developing for the past five decades and in the 1980s it was widely used as part of their successful electrification programme (GNESD, 2006; Yao and Barnes, 2005). In Indonesia, over 100 mini-hydro installations have been introduced, ranging between 7 and 250kW and serving 20,000 households. 85 per cent of these were locally manufactured, resulting in cost savings of approximately 40 per cent. Compared with the equivalent use of diesel generators, the emission of more than 4000 tonnes/year of CO<sub>2</sub> was saved (although the size of the diesel generators used for comparison is not specified) (GTZ, undated-a).

Micro-hydro plants can be used to generate electricity for household use or battery charging, or to provide mechanical power in productive end uses such as milling or water pumping for irrigation. User needs and suitability for the location and community must be prioritised when selecting the type and size of plant. One sensible maxim is that 'it is easier to make a profitable micro-hydro plant socially beneficial than to make a socially beneficial plant profitable' (Khennas and Barnett, 2000a), and thus commercial end uses should be maximised wherever possible. This was seen in Nepal in 1996, where over four fifths of the 900 micro-hydro plants introduced were for milling purposes (Khennas and Barnett, 2000b). Nevertheless, commercial uses of micro-hydropower may not always be available, making it difficult to cover the high upfront costs of installation.

Despite the relative advantages of micro-hydro, it is still said to be 'significantly under-utilised' (Cherni *et al.*, 2005, p. 33). But although a large number of potential hydro sites do exist, many are located in inaccessible areas, making it difficult to transport the necessary equipment to harness this energy source (REN21, 2005a). Furthermore, as micro-hydropower relies on the availability of sufficient water resources, in areas where this is becoming more and more unpredictable because of variable rainfall patterns and increased drought, this can lead to changes in river flow and low power outputs (GNESD, 2007). Some rivers do continue flowing during drought periods and assessment of long-term flow records (if available) can prove valuable in determining whether this is the case at the start of a project (Practical Action, 2009c). In addition, disruptions to the water cycle can also result from nearby activities such as deforestation within catchment areas, and it is important to do a thorough analysis at the planning stage to find out whether this is a potential risk (Giri *et al.*, 2004). At the other extreme, excessive rainfall can lead to landslides, blocking water channels and disrupting micro-hydro plants. Thus the viability of micro-hydropower can be threatened by a number of factors which makes its use very context specific.

**Wind power** – Wind has been used to generate mechanical power for centuries and electricity for several decades. It inevitably relies on the availability of wind resources, which vary hugely within and between regions (Gross *et al.*, 2003). Wind power can be used to generate household electricity either directly or through battery charging, or for non-electrical uses such as water pumping for irrigation purposes (REN21, 2005a). Various different sizes of wind turbines exist, but decentralised wind energy systems tend to range between 50W-2kW for micro wind energy and 2kW-40kW for small wind energy systems (Spera, 1994; Gipe, 1999, both cited in Practical Action, 2008b).

There has been a lot of emphasis on wind generation of electricity (GNESD, 2007). Where there is sufficient wind, small wind systems can have an advantage over alternatives such as solar PV systems both in terms of power generated and cost per power unit. For example, in Peru the cost of wind energy for a 100W wind generator was found to be 13-72p/kWh, compared to 76p/kWh for a solar home system (SHS), both of which are significantly higher than the cost of micro-hydro (Dunnett, undated). Projected wind generated energy costs in Sri Lanka were found to be even higher, at 63p-91p/kWh. The wide range of these costs is due to differences in the local wind regimes.

Wind energy projects have not always met with success. Failures are often due to simple bad planning as was the case during the 1980s in Senegal where only 40 per cent of the original 200 wind pumps installed were found to be operational after three years (GNESD, 2006). The same report notes more recent efforts have involved a more sustainable approach, seen by the successful 'Vent Eau pour la Vie' (wind/water for life) programme in Senegal. In China, wind power has been particularly successful, and China remains the world's greatest manufacturer of micro and small wind turbines (REN21, 2005b). In 2005, Chinese wind farms



had a capacity of approximately 1280 MW, and this is predicted to rise to nearly 10,000 MW by the end of this year (GTZ, undated-d). China is said to have even greater potential than that (Chemi *et al.*, 2005). According to Practical Action, Inner Mongolia in China hosts one of the best examples of a small-scale decentralised wind energy programme, where over 500,000 people have been given access to electricity from over 130,000 wind turbines, ranging between 200W and 1000W (Practical Action, 2008a).

Non-electrical uses of wind power are especially attractive for improving the livelihoods of the poor, because of their simplicity and reliability. Where the surrounding wind resources are consistent and manufacture is carried out locally, wind-driven water pumps are cost effective in comparison to water pumps powered by other sources (Balla, 2005). They also cost significantly less than wind energy turbines that generate electricity; a project in Egypt showed that a wind turbine to pump water cost \$2500 versus \$4000 for a wind turbine to generate electricity (UNDP and GEF, undated). In 2005 there were around 1 million wind pumps, with the majority found in Argentina and southern Africa (REN21, 2005a). Due to preconceptions and a lack of awareness, governments and developers have frequently dismissed mechanical wind power in favour of electricity generating wind turbines, with wind pumps often referred to as an ancient and inappropriate technology (GNESD, 2007). Without government support and political will, it will be difficult to channel further funds into the development of this technology.

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As with other renewable energy technologies, some of the main constraints to the development of wind energy include a lack of local technical capacity for installation, operation and maintenance, availability of spare parts and limited funding for research and development. Nevertheless, where there is sufficient capacity building, local communities can become involved in many of the areas mentioned above. Technically, wind generators are more vulnerable than other renewable energy systems, especially the rotating components, and small changes in wind speed can have a large effect on energy output (Gross *et al.*, 2003). They involve a relatively high capital cost, but if systems are manufactured locally it can not only help lower these costs but also create local production markets and greater opportunities for good operation and maintenance.

**Solar** – Solar energy has been one of the most popular renewable energies (REs) driven by the donor community. Table 4 shows a summary of various solar technologies. As solar PV has been one of the most common solar technologies pursued, this is discussed in more detail.

**Table 4.** Summary of various solar energy technologies

Technology	Description	Benefits
Solar water heaters (SWH)	A system that utilises energy from the sun to heat up water.	Provides households with hot water. This industry is well established in South Africa and China, where 250,000 have been installed. N.B Piped water is normally required.
Solar lamps	Uses solar energy for lighting purposes	Low cost and can supply good quality light for around 6 hours.
Photovoltaic (PV) systems	<p>Solar home systems (SHS): small, stand-alone electrical systems, which can provide a reliable energy source. It consists of a photovoltaic module and a rechargeable battery<sup>3</sup> for electricity storage providing 24 hour use, a charge controller, fluorescent lamps, wiring and fixtures.</p> <p>Photovoltaic water pumps</p> <p>Photovoltaic battery charging stations</p> <p>Grid-connected photovoltaic systems</p>	<p>Provides electricity for improved lighting and to power radios, TVs and phone chargers; reduces smoke fumes and risk of fire/burns.</p> <p>Improved household water supply or irrigation systems. Globally, there are more than 50,000 PV pumps.</p> <p>Used to charge batteries for household electricity use.</p> <p>Generate electricity for distribution within the national grid.</p>
Solar cookers	A cooking appliance that runs purely on solar energy.	Replaces traditional biomass or conventional fuels, providing health benefits and time savings.
Solar dryers	Used to dry agricultural products	Enables better quality food preservation.

Source: Created by authors using material sources from Barua, 2008; GNESD, 2006, 2007, 2008; REN21, 2005a, 2005b; ARE, undated; Practical Action, 2007b.

3. Disposal of solar charged batteries is an environmental and health risk (Hofmann *et al.*, 2009).

**Solar photovoltaic (PV)** – International multilateral organisations such as the World Bank and the UNDP and large energy companies such as Shell, BP and Total, are often behind the dissemination of large-scale PV systems for electricity generation (Greenpeace and ITDG, undated; Practical Action, 2006b). In China, Shell distributed 60,000 SHSs and the World Bank’s China Renewable Energy Development project, ending in 2008, installed more than 400,000 households with solar PV systems (Greenpeace and ITDG, undated; REN21, 2009). Similarly, in Sri Lanka, the World Bank recently funded a project where 125,000 households were installed with SHSs. One consequence of this concentration on PV is that it can overshadow and limit funding for the development of other more appropriate renewable energy solutions (Practical Action, 2009b).

Even though solar PV has been widely used, there are still several barriers that remain, including technical problems limiting the quality of electricity produced, and a lack of understanding of how it is used and what it can and can’t provide (Cherni *et al.*, 2005). Many of the components are usually imported, making it difficult to find locally available spare parts and reducing the extent to which local communities can become involved in the distribution of this energy source through local manufacture. In addition the high cost of electricity per power unit means that they can be too expensive for use in income generating activities and where they have been used for productive activities, these have tended to be within wealthier consumption sectors (Karekezi, 2002). In addition, despite a steady drop in cost over time, the high capital cost of PV systems (explored below in the Grameen Shakti programme case study) means that they remain largely unaffordable for the poorest households who depend heavily on subsidies to be able to access them (GNESD, 2006).

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While solar home systems can be too expensive at the household level, solar energy technology has been shown to be particularly beneficial at the community level. In health centres, they can prolong the life of vaccines through refrigeration, and provide sterilisation facilities, better lighting for treatment and operation, and incineration of medical waste (Hofmann *et al.*, 2009; REN21, 2005a). In schools, solar generated electricity can provide better lighting and improve education facilities. In Cuba, the NGO CubaSolar supplied electricity using solar energy to a total of 200,000 surgeries in rural areas and to 2000 rural schools (Cherni *et al.*, 2005).

**Biomass** – Traditional biomass vastly exceeds such alternative renewable energy sources in terms of access by the poor, with approximately 2.4 billion people using biomass to meet basic household needs such as cooking and heating. This amounts to around half of the population in developing countries (see Table 2) (OECD and IEA, 2006). The dependence on biomass in sub-Saharan Africa is particularly high (89 per cent of the population).



Photo: Mike Goldwater

**Traditional forms of cooking over an open fire are very inefficient**

As noted in Chapter 1, traditional biomass such as fuelwood or agricultural waste is often labelled in the literature as ‘unsustainable’ (Olz *et al.*, 2007, p.15), ‘inefficient’ (GNESD, 2006, p.9) and linked to environmental degradation (Gross *et al.*, 2003) and under-development (GNESD, undated). In many cases national energy statistics do not even include data on it (Openshaw, 2010). But such views need to be revised in light of a massive global effort to install improved stoves, understanding of the sustainable management of biomass and a wealth of new technology to produce electricity and a variety of liquid and gaseous fuels with low net CO<sub>2</sub> emissions from biomass.

These negative perceptions are often based on experience in non-OECD countries of fuelwood and charcoal being produced and used in very detrimental ways and this should not be discounted. Instead, we argue that there are increasing numbers of examples of biomass resources being used sustainably, efficiently and using modern technologies. For example, in a recent global review it was concluded that deforestation from biomass use is often not because biomass demand is out of balance with wood stocks, but due to failures to provide incentives to manage wood production in a manner that allow regeneration in and around wood harvesting areas (Arnold *et al.*, 2006). In many non-OECD countries, energy efficient cooking stoves, effective use of agricultural wastes and new electricity generating options are expanding rapidly. As for modernity, in OECD countries such as Denmark, biomass co-generation (from wood waste) and biogas (from straw and animal waste) produces approximately two-fifths of the electricity generated (Sims *et al.*, 2003). We discuss some of the different biomass energy options below.

According to the Global Network on Energy for Sustainable Development (GNESD): 'firewood (if extracted in a sustainable manner) and livestock manure converted into biogas are the renewable biomass resources with the highest potential to meet the energy needs of the poor' (GNESD, 2006, p.37). Peri-urban communities are particularly suited to biomass energy, with the advantage of being able to access natural resources, whilst having accessibility to markets in urban areas.

Compared to other renewables such as solar or wind power, this form of energy does not suffer from intermittency and it is less region-specific. It can also serve in arid areas where water for micro-hydro is scarce. Nevertheless, the extent to which it is used and its application is largely dependent on existing land use or agricultural practices, the local climate and the seasonal availability of crop residues (Openshaw, 2009). Moreover, the time consuming task of collecting biomass resources can be a disadvantage in areas where other renewable energy sources are also freely available and where the use or involvement in biomass energy supply does not result in sufficient economic revenues. Other obstacles include the absence of policy and regulatory frameworks for its use and the lack of infrastructure and skilled personnel to build capacity in the sustainable management and processing of this resource (GNESD, 2009).

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**Fuelwood, charcoal and energy efficient stoves** – In many developing countries, fuelwood is an important resource and national asset, used by many of the poor to meet their energy needs. It has been estimated that poor households spend at least one-fifth of their monthly income on wood and charcoal (Barnes *et al.*, 2005). This represents a huge economic resource. As noted above, earlier concerns that demand for fuelwood and charcoal was outpacing sustainable supply on a scale that makes it a major cause of deforestation are not supported by the available evidence (Arnold *et al.*, 2003). There is now renewed interest in the use of fuelwood and charcoal, used alongside sustainable harvesting practices, as a sustainable energy source for rural communities (Gross *et al.*, 2003). Where the economic and social benefits are clearly identified, there are incentives for communities to protect the forests and secure a continuous supply of fuelwood. But their adherence to sustainable management practices can be thwarted by corruption, insecure land tenure and a lack of enforcement (GNESD, 2006).

In order to combat real inefficiencies in wood use and health hazards in the home, much attention has been paid to energy efficient stoves (Goldemberg, 2000). These use around half the fuelwood that traditional stoves use and are very cost efficient, with a payback time of only a month in some regions (Hofmann *et al.*, 2009; GNESD, 2007). In Senegal, stoves cost approximately US\$ 9.86, with US\$ 6.57 saved per month on charcoal expenditure (GTZ, undated-c). Traditionally, a three-stone fire is used for cooking, which loses approximately 90 per cent of its energy and emits harmful smoke emissions contributing to indoor air pollution, leading to 1.5 million deaths per year, mainly among women and children (REN21, 2005a; WHO, 2006).



Photo: Mike Goldwater

Poverty trap or fuel of the future? Delivering charcoal door to door in Mozambique

Improved stoves can lead to health benefits by reducing smoke emissions, provide cost savings in fuelwood collection and free up women and girls' time for more productive uses ( Hofmann *et al.*, 2009; REN21, 2005a). Their simplicity allows domestic markets to grow up for their manufacture and sale, opening up avenues for local employment (GNESD, 2007). In most cases, revenues generated from building improved stoves contribute to household income, rather than providing the sole income source. In some circumstances ,where women are involved in the manufacture of stoves, this can help improve their social status within a community (Hofmann *et al.*, 2009). In total, approximately 220 million people are thought to own improved stoves, mainly in China, India and Africa, with over half of these met by the Chinese National Improved Stove Program, which saw the introduction of 120 million stoves among rural households (REN21, 2005b; World Bank, undated-b). They were a significant element of the EnDev programme (discussed as a case study below), where 775,000 improved stoves were distributed in 15 different countries (Hofmann *et al.*, 2009).

Some of the disadvantages associated with improved stoves include the need for a specific size of fuelwood which can be inconvenient and the fact that not all standard pot sizes fit on these stoves (Openshaw, 2009). If shortage of fuelwood is not an immediate problem for a community, then households may have little incentive to adopt these stoves unless they provide economic benefits. Communities where cooking is carried out outdoors, minimising the negative impact from smoke emissions, may not see the need for improved stoves. Lastly, not all energy efficient stoves can provide space heating, which may deter some communities who require this.

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Nevertheless, despite their simplicity, the distribution of energy efficient stoves can be an excellent renewable energy option with a high replication value, bringing various benefits to a community (Scheraga *et al.*, 2000). This is especially true amongst heavily biomass-dependent communities, who may show reluctance to substitute biomass with other cooking fuels (TERI, 2008).

**Biofuels** – As noted in Chapter 1, biomass can also be converted to a range of different energy carriers, albeit with conversion inefficiencies and processing costs. The use of liquid biofuels for transportation has been expanding. The precedent was set by Brazil in the 1970s, producing bioethanol predominantly from sugarcane. In 2006, Brazil produced 17.8 billion litres of bioethanol; the United States produced 18.5 billion litres of it from corn and Europe 1.6 billion litres from sugar beet and wheat (Solomon *et al.*, 2007). In the 1990s, biodiesels made using vegetable oil as feedstocks (such as soybean or rapeseed oil) have emerged. In 2006, these amounted to 1 billion litres in the United States and 4.5 billion litres in Europe (IEA, 2008). A range of issues have emerged as biofuel markets have undergone their recent expansion. These include the risks that energy crops will displace agricultural food crops and more generally exacerbate the conversion of forests into agricultural land (Dufey, 2006). There are significant questions about the degree to which the biofuel boom can be inclusive and serve the needs of development and the poor.



In non-OECD countries, one biofuel that is exciting great interest is the use of *Jatropha* for biodiesel production, due to its ability to grow on marginal land with minimal water (GNESD, 2009). Multi-functional platforms using unrefined *Jatropha* oil for small-scale agriculture processing and electricity generation have been successful in many African countries with income diversification through by-products such as soap or fertiliser (UN, 2007). Unfortunately, without strong frameworks and policies in place to monitor this growth, private companies are beginning to extend the cultivation of this plant onto agricultural land, leading to food security concerns. Where *Jatropha* is planted on marginal land, low yields may mean more land has to be planted which has a particularly acute impact on the poorest segments of society, who often depend on marginal land for green-fallow agriculture or livestock grazing (Joongschaap *et al.*, 2007). In West Africa, almost one-fifth of agricultural land is now either being used to grow *Jatropha* or earmarked for it in the future use (GNESD, undated). Recent studies in Mali, Mozambique and Tanzania have shown that *Jatropha* developments are being driven by early adopter European companies (themselves driven by the 'artificial' market created by the EU biofuel directive) and that there may be ways of encouraging the inclusion of smallholders through outgrower schemes, joint ventures and so on, as described in Figure 8 (Vermeulen *et al.*, 2009).

On the one hand, biofuels can be 'instrumental in bringing an agricultural renaissance that revitalises land use and livelihoods in rural areas' (Cotula *et al.*, 2008). The additional value offered by biofuel crops can help smallholders increase returns and consolidate their land holdings or offer increased opportunities for waged employment. On the other hand, if there is insecure land tenure, a rapid expansion of biofuels can dispossess poor people. These processes are increasingly documented by a growing body of evidence on the negative impacts of large-scale commercial biofuel production for access to land, drawing on contexts as diverse as Africa (for example Tanzania and Mozambique), Latin America (Colombia and Brazil), and Asia (India, Indonesia and Papua New Guinea) (Cotula *et al.*, 2008). The authors of Cotula *et al.* argue that governments can do much to mitigate the potential impact on the poor by developing clear definitions of 'available land', robust safeguards for fair land allocation, financial incentives for smallholder inclusion, fair tax, trade and employment legislation, and a commitment to developing the capacity of local associations and pro-poor business models.

**Biogas** – Biogas is increasingly being used for cooking, lighting, thermal requirements and even electricity generation (Practical Action, 2006a, 2007a). The basic principle of a biogas plant is simple: organic material, for example livestock dung, is collected in a digester tank and decomposed by bacteria anaerobically, producing biogas (mainly methane and carbon dioxide) and a solid residue which can be used as a fertiliser (Barua, 2008). Operating conditions (high temperatures, an airtight container and specific levels of humidity) need to be strictly adhered to in order to maintain reliable supplies of biogas. Biogas replaces the need to use fuelwood or LPG for cooking, reducing smoke emissions, and providing financial and time savings. Improved sanitation can also arise where human excreta is used.



Depending on the amount of livestock or agricultural waste available, biogas plants can vary in size. An average biogas plant of 6-8 m<sup>3</sup> costs US\$ 200-250 if locally manufactured and can produce 300 m<sup>3</sup> of biogas annually, making them cost effective (REN21, 2005a). If large enough, biogas plants can be used to generate electricity. Their simplicity makes them an attractive technology, as they can be built locally with basic training.

In 2005, biogas plants were used by 16 million rural households for cooking and lighting purposes in developing countries, with 12 million of these households found in China (REN21, 2005a). India has also witnessed the successful introduction of biogas plants, such as the 60,000 introduced in southern India using surplus cow manure, with 95 per cent still working effectively after five years of operation (GNESD, undated). Following the US Agency for International Development's (USAID) Nepal Biogas Microfinance Capacity Building Program, various financial institutions have been set up in Nepal to promote development of this sector (Practical Action, 2006a). China is probably the leading developer of biogas with more than 30 million units now installed at a rate of about 6 million per year (Gregory, 2010).

Where animal manure is used as a feedstock, there needs to be a continuous supply which can make the technology inaccessible to poorer households without livestock, although there are some technologies which can produce biogas from fuel crops (Practical Action, 2006a). For the best results, the biomass needs to be mixed with the same volume of water to make it flow better, which may impose a constraint in areas where reliable water supplies are not readily available. Biogas energy users tend to reside close to the plant, due to practical considerations of collecting the feedstock and supplying the gas to households and biogas plants may therefore not be suited to widely dispersed communities (Barua, 2008). Where livestock roam freely, systematic collection of cow manure can be difficult, and specially adapted cattle sheds near feeding stations have been used by some communities (Practical Action, 2006a, 2007a). As with other renewable energy systems, operation and maintenance is vital for project success; in Sri Lanka, where this was neglected, two-thirds of the 5000 biogas plants introduced were no longer in working condition at the time of inspection (Practical Action, 2007a).

Biogas plants are a promising technology, but there may not always be a demand for biogas as a fuel. Not all cultures or religions are open to the re-use of animal or human waste in the form of a gas or fertiliser (Ngobi, 2007). According to Islamic religious beliefs, human excreta is classified as one of several spiritual pollutants and Muslims are discouraged from any type of close contact with it (Edwards, 1992). The need for an alternative cooking fuel may not necessarily be a priority, as seen in south India, where a biogas project initially failed, due to abundant supplies of locally available fuelwood, with the community more concerned about a lack of clean water (World Bank, undated). Consequently, biogas plants were redesigned for electricity generation to pump water. Being constantly aware of user needs and cultural barriers can ensure that the correct type of technology is introduced into a community.

**Biomass gasification and electricity generation** – Biomass resources can also be turned into a gas which is burnt to generate electricity (GNESD, 2007). Biomass gasifiers are a low cost, highly efficient technology, with fuelwood savings of up to 60 per cent (GNESD, 2006). They can use forest or agricultural waste as a feedstock, which simultaneously provides a solution for its disposal. The use of biomass gasification can be applied to both household and industrial settings and has been particularly successful in China and India, examples of which are discussed below.

In China, a project designed for a village of 320 households aimed to provide a combined gas (for household use) and power supply (for better irrigation systems through groundwater pumping), using crop stalks as a feedstock currently left abandoned after harvesting (GNESD, 2007). This provided not only an additional income source from the sale of the crop stalks, but also employment opportunities from the operation of the gasifier plant and a cheaper energy supply than coal or LPG.

In India, the potential of biomass gasification for electricity generation in remote rural areas beyond established grid networks has been explored. In 2004, the total potential power that could be generated from biomass was 19,500 MW (GNESD, 2006). Biomass power generating systems in India have been largely developed over the past two decades by the Ministry of Non-Conventional Energy Sources (MNES), with the advantage that a wide range of biomass gasifiers with capacities of 5-1000 kilowatt (electrical) (kW<sub>e</sub>) have been locally developed and not imported from developed countries as is often the case with other renewable energy technologies (MNES, 2005; Nouni *et al.*, 2007). The MNES commenced the remote village electrification programme in 2001-2002, with a large focus on biomass gasifiers for electric power generation (MNES, 2005; Nouni *et al.*, 2007). This programme had introduced 1844 biomass gasifier system for electricity generation by the end of 2004, amounting to a total capacity of 62 MW (MNES, 2005).

A detailed financial evaluation of biomass gasifier projects for decentralised power supply in India found that the levelised unit cost of electricity (LUCE<sup>4</sup>) for dual fuel (DF) biomass gasifiers (run together with diesel) were particularly competitive with diesel generators for capacities of 20kW or higher at an operating load of 100 per cent. (Nouni *et al.*, 2007) Those run on 100 per cent producer gas (HPG) are not cost effective compared with diesel generators at any capacity (Table 5). As the operating load decreases, the LUCE cost of DF and HPG biomass gasifiers, and diesel generators rises steeply, with the result that DF is no longer cost effective compared to diesel generators. These costs are of course specific to India, but nevertheless provide a good indication of the cost effectiveness of biomass gasifiers in relation to conventional energy sources.

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4. These are at 2006 prices, where 1 US\$ = Indian Rupees (Rs.) 44.14 on 30 January 2006 (Nouni *et al.*, 2007).

**Table 5.** Comparison of LUCE for DF biomass gasifier power projects (BGPP), HPG BGPP and diesel generators in India

Operating load of power generating system as a percentage of its rated capacity	Levelised unit cost of electricity (LUCE in US\$/kWh)											
	Dual Fuel					100% Biogas		Diesel generating set				
	Rating capacity (kW)					Rating capacity (kW)		Rating capacity (kW)				
	5	10	20	30	40	9	40	5	10	20	30	40
100	0.55	0.37	0.29	0.33	0.29	0.40	0.33	0.46	0.37	0.31	0.31	0.29
75	0.66	0.44	0.33	0.37	0.33	0.51	0.40	0.53	0.40	0.33	0.33	0.31
50	0.95	0.62	0.46	0.51	0.40	0.75	0.58	0.71	0.40	0.40	0.40	0.35

Source: Adapted from Ea Energy Analyses, 2008

An industrial use of biomass gasification in India can be seen within many small and micro enterprises (SMiEs), which are extremely important to India's manufacturing sector (GNESD, 2007). At the end of the 1990s, India's rubber processing and metallurgy sectors suffered greatly due to increasing electricity costs. The introduction of biomass gasifiers helped lower these fuel costs – for example, the cost of annealing processes fell by more than 50 per cent – and the profitability of these SMEs was therefore maintained.

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Other regions of the world where biomass gasification is underway is Brazil, where the *Luz Para Todos* ('light for everyone') programme last year saw power introduced to villages using vegetable oil and gasified/wood residues (REN21, 2009). Biomass gasification for electricity production for isolated communities in the Brazilian Amazon region is also being tested, as an alternative to diesel generators (GNESD, 2006). For example, in Aquidabam village, a 20kW gasification systems was introduced, using locally available eucalyptus chips, *cupuaçu* (an Amazonian fruit) and *babaçu*. It is hoped that this plant will be able to produce eight hours of electricity per day, which could replace three-quarters of the diesel currently used.

Although power generated through biomass gasification is growing, it still encounters technical difficulties such as the need for a constant demand for electricity in order for the plant to operate (Gupta *et al.*, 2008). This can be difficult to establish in some communities, because of scattered and low demand. Agricultural waste such as crop stalks may also not necessarily be available year round for continuous operation of the plant, and an alternative fuel source during these periods needs to be considered. In addition, a reliable feedstock requires the collection of biomass waste to be well organised. Moreover, there is a lack of awareness among producers of the energy potential of their agricultural and forest residues, which could be greatly enhanced by increased government support. There is also the assumption that agricultural and forest residue

producers will be those using the energy, but where this is not the case adequate links between residue producers and energy users need to be established (GNESD, 2006).

**Mixing and matching** – A broad range of feasible renewable energy technologies exist and biomass certainly ranks among the more promising technologies. If sheer accessibility and use by the poor were decisive factor in selecting which option to pursue, biomass energy would dwarf these other alternatives. China and India appear to be one step ahead in the use of renewable energy systems, with some clear example of where these have reached poor rural communities. Even though the technologies have been mostly discussed separately, this report also acknowledges the importance of hybrid technologies, mixing biomass with other alternatives which can spread risk and overcome problems of intermittency in some of the other technologies (Chaurey *et al.*, 2005).

The benefits of using multiple energy sources to power rural communities include a much lower risk and dependency on single source fluctuations (such as variable wind conditions, cloud cover or water availability). For example, in Malaysia combined solar, wind and diesel systems were able to provide steady electricity supplies independent of weather conditions (Darus *et al.*, 2009). Where the cost and availability of fossil fuels are an issue it is increasingly practical to substitute biomass for the diesel 'back-up' of such hybrid electricity systems. Such combinations can make use of the strengths of each energy source, while offsetting weaknesses (Kidani, 2004).

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One of the problems of developing such systems for use with centralised grids is to ensure that the combination of feed-in tariffs and other incentives for developing biomass technology make the often commercially under-developed biomass competitive with other energy sources. In Europe, Renewable Portfolio Standards are a popular policy vehicle for achieving this. Green certificates, sometimes called tradable renewable energy certificates (TREC)s, are issued to producers as proof that a certain amount of energy has been generated from renewable sources (APEIS, 2004). The requirements for 'green certificates' for renewable energy are weighted in such a way that certificates for under-developed energy sources are given a premium to encourage their installation.

The United Kingdom is one country where such a system operates. The UK government adjusts upwards the percentage of green certificates known as Renewable Obligations (a percentage of the energy that any supplier must source from renewable technologies). By varying the weighting of different renewable energy technologies using a system of tradable Renewable Obligation Certificates (ROCs) the UK government can encourage investment into technologies that require market support. For example, dedicated biomass electricity generation was recently upgraded to a ROC rating of 1.5 whereas co-firing of biomass in conventional power stations receives a ROC of only 0.5. Sourcing energy from dedicated biomass power stations will therefore count three times higher towards

the renewable obligation than co-firing would. Similar policies to encourage investment in new biomass energy technologies should have a central place in energy policies.

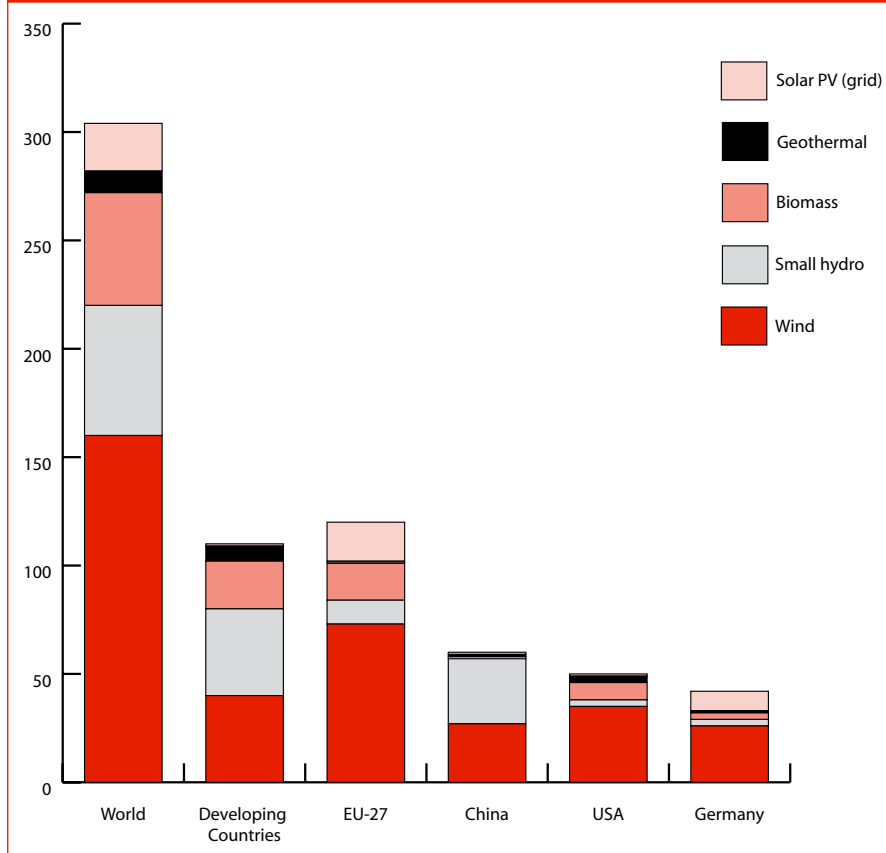
Yet it is beyond the centralised grid that hybrid systems can come into their own. Hybrid energy systems involving biomass are particularly attractive for meeting the energy needs of communities in remote areas. For example, if the total load cannot be met by a single energy source, two or more renewable energy systems can be combined. For example, 60 per cent from a biomass system, 20 per cent from a wind energy system and the remainder from fuel cells. To get a constant power supply, the output from the renewables may be connected via a rechargeable battery bank to the load. If the load is alternating current (AC), then an inverter can be used to convert the direct current (DC) supply from the battery to the AC load.

**The need for research and development** – The development of biomass energy options and possible hybrid systems is not something that can occur in a vacuum. It requires government support for research and development. A case in point is India. In 1981 the government of India established a Commission for Additional Sources of Energy (CASE) in the Department of Science and Technology. The mandate of CASE was to promote research and development in the field of renewable energy including biomass. In 1982, CASE was formally incorporated in the newly created Department of Non-conventional Energy Sources (DNES) which in 1992 became the Ministry for Non-conventional Energy Sources (MNES) (TERI, 2005). MNES has provided financial support to renewable energy industries for research and development projects in association with Indian technical institutions. This has been backed by a comprehensive package of incentives. For example, industrial clearances have not been required for setting up renewable energy industries in India. No clearance has been required from the Central Electricity Authority (CEA) for power generation projects below a certain financial threshold. A five-year tax holiday has been in place for renewable energy power generation projects. In addition, soft loans have been available through the Indian Renewable Energy Agency Ltd (IREDA) for renewable energy equipment manufacturing (NRI, 2005). For example, in 2005 IREDA was providing loans at an interest rate of 11 per cent for biomass co-generation projects and at 10.5 per cent for biomass power projects. The repayment period was set at 10 years plus a three-year grace period. For both types of project the maximum loan equated to 70 per cent of the total project cost. For biomass power projects, the generating capacity needed to be between 1.0 -7.5 MW in order to qualify. Furthermore, customs duty concessions have been available for renewable energy spares and equipment, including those for machinery required for renovation and modernisation of power plants. Excise duty on a number of capital goods and instruments in the renewable energy sector has also been reduced or exempted. With such an emphasis on support for research and development of new technologies it is no wonder that India's capability is developing fast, a track other countries could follow.

## Status of renewable energy programmes in non-OECD countries

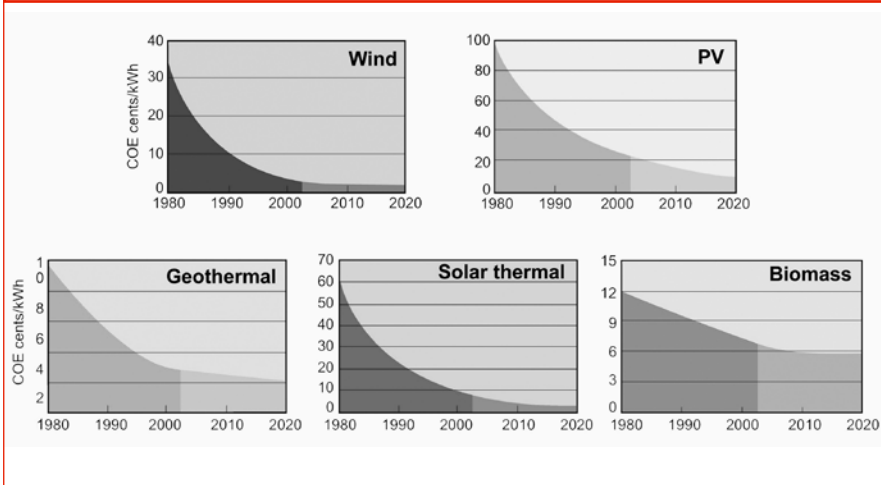
General trends show a renewed interest in and uptake of both off- and on-grid renewable energy systems, which have been growing steadily over the last decade (REN21, 2009). Figure 14 outlines the renewable electricity generating capacity in different regions of the world in 2009. This heightened interest has been due to a number of reasons including the desire to reduce greenhouse gas (GHG) emissions in light of growing climate change concerns, the potential for energy independence and security (GNESD, 2007), a drop in the cost of renewable energy technologies (Figure 15; REN21, 2005a), and the availability of more reliable and efficient systems (AusAid, 2000; OECD and IEA, 2004).

**Figure 14.** Renewable electricity power capacities: by region and top three countries in gigawatts



Source: REN21, 2010

**Figure 15.** Drop in renewable energy cost (levelised cents/kWh in constant US\$ at 2000 prices), with predictions provided for 2002-2020



Source: NREL, 2002. NB these graphs reflect historical cost trends NOT precise annual historical data

Despite this growing global trend towards renewable energy, some early examples of programmes in non-OECD countries have produced disappointing results and even the abandonment of the technology, creating some disillusion among development practitioners. Failures have been attributed to: the unsustainable nature of projects arising from top-down initiatives, a lack of community participation, insufficient user information and training, poor operation and maintenance, inaccurate assessment of local conditions, and poor socio-cultural sensitivity. Too often inappropriate technology choices have failed to meet community needs (AusAid, 2000; GNESD, 2006, 2007; Cherni *et al.*, 2005). Among these unsuccessful projects was one installing biogas-powered water pumps in the Philippines during the 1980s, which quickly fell into disarray, with only 1 per cent still in use after a few years (Martinot *et al.*, 2002). The failure of renewable energy projects in the past was also attributed to fragmented and isolated efforts, poor integration with other development programmes and lack of institutional collaboration (GNESD, 2007). With energy intrinsically linked to all aspects of development, projects focusing solely on energy provision without considering the context in which it will be used have had little chance of success.

The Earth Summit in Johannesburg in 2002 led to a committed United Nations effort to promote reliable and affordable renewable energy to meet the MDGs (UN-Energy, 2005). Ten different renewable energy programmes from across the globe highlight the diversity in energy sources that have been promoted in such systems with biomass energy playing a modest role in India (some biomass gasifiers) and Bangladesh (improved cooking stoves). What is still lacking is sufficient awareness among consumers and decision makers about the broader

potential of biomass energy and how to improve opportunities not just for access to energy, but also involvement in its supply. This awareness needs to be increased, through information campaigns and education, to allow for better informed choices (GNESD, 2006).

**Table 6.** Examples of nine renewable energy programmes in the developing world

Name of the Programme	Country	Details
The Brightness Programme introduced in 2000 by the Chinese government.	China	This promoted micro-hydropower, small-scale wind power, small PV systems and hybrid systems (eg wind/PV) to 30 million individuals who did not have electricity.
National Township Electrification Programme introduced in 2002.	China	Harnessing renewable energy (mainly PV and small-scale hydropower) to provide electricity to the 1061 townships without electricity.
India's Remote Village Electrification Program	India	4250 villages and 1160 hamlets provided with a renewable electricity source by the beginning of 2009, using PV, solar lanterns, solar-powered water pumps, solar cookers and small-scale biomass gasification systems.
Rural Energy Development Program	Nepal	In 1996, 15 districts saw the introduction of micro-hydro plants.
Global Environment Facility (GEF) and UNDP funded wind energy project.	Eritrea	Introduction of a small 750 kilowatt wind park and 8 small-scale wind and wind-diesel hybrid systems for electricity generation in rural villages.
Peruvian Rural Electrification Plan	Peru	Aim of expanding electrification to the rural population, including the use of renewable energy sources in areas where it is economically viable.
Integrated Energy Services Project for Small Localities of Rural Mexico	Mexico	Between 2006 and 2011, promotion of renewable energy sources for off-grid electrification schemes, using PV systems, small wind power systems and to a lesser extent micro-hydropower and biomass-fuelled generators supplying small isolated grids.
The Energising Development (EnDev) Programme	21 developing countries	Between 2005 and 2009, a total of 24 activities were carried out, to improve energy supply using renewable energy using improved cooking, SHSs and micro-hydro plants, as well as central or mini grid connections.
Grameen Shakti	Bangladesh	Implementation of renewable energy technologies, including PV SHS, biogas plants and improved cooking stoves.

Source: Created by authors from OECD and IEA, 2009b; UNDP and GEF, 2003; Mansingh, 2005; REN21, 2009; GNESD, 2006; Barua, 2008; Hofmann *et al.*, 2009



**Uses of renewable energy** – A wide range of energy services can be met through renewable energy. Household energy consumption is widely variable between developing regions and as such it is difficult to provide a specific breakdown, but the primary use of household energy is generally to meet cooking needs (OECD and IEA, 2006). Approximately four-fifths of the total energy expenditure amongst poor households is spent on cooking fuel, mainly biomass sources (UN-Energy, 2005). Where electricity is available, this is largely used for lighting and small appliances and amounts to a small proportion of total household energy consumption (OECD and IEA, 2006). Mechanical power is also extremely important, but used more in productive applications. Consequently, poor households need a differentiated approach recognising their multiple energy needs. Table 7 gives a breakdown of the energy services provided by a range of different renewable energy technologies.

The focus of renewable energy programmes is an important issue. Many argue that the biggest potential for poverty alleviation arises when renewable energy programmes supports income-generating opportunities. Focusing on enterprise and income generation can make projects more cost effective and financially attractive to potential investors (REN21, 2005a). Moreover, the larger and more constant energy demands from enterprises make it easier to repay start-up costs in comparison with projects designed purely for household energy needs. Some potential income generating opportunities that might form the focus of renewable energy programmes are highlighted in Table 8. Meeting basic needs such as cooking, heating and lighting are clearly important for sustainable development but do not necessarily ensure that communities will cross the poverty threshold (TERI, 2008). Where energy enhances the productivity of an already existing business or where communities are provided with support for the development of entrepreneurial skills, productive use of renewable energy can be extremely effective (Hofmann *et al.*, 2009; GNESD, 2006). Nevertheless, we should not assume that income generating opportunities will arise automatically immediately following the introduction of renewable energy technologies into a community or that they are always possible (Hofmann *et al.*, 2009; AusAid, 2000; GNESD, 2006). In very isolated communities, it can be difficult to use renewable energy for productive activities, as local markets tend to be rather small and access to wider markets limited because of terrain or road conditions. Hence, there is the need to consider energy as part of a more holistic 'development' package, to ensure the best energy use possible.

**Table 7.** Outline of the different energy services provided by renewable energy technologies

Renewable energy technology / application	Energy service	Where
Solid biomass	Cooking and lighting (direct combustion), motive power for industry and electric needs	Mostly rural
Liquid biofuel	Transport fuel and mechanical power, particularly for agriculture; heating and electricity generation; some rural cooking fuel	Urban and rural
Biogas	Residential and industrial electricity (grid connected), cooking and lighting (household-scale digesters), motive power for industry and electric needs (with gas engine)	Urban and rural
Biomass gasification	Power for industry and electric needs	Mostly rural
Solar PV	Residential and industrial electricity (grid connected)	Mostly urban
Solar Home Systems (SHS)	Lighting and other low to medium voltage needs such as telecommunications	Urban and rural
Solar PV pumps	Pumping water for agriculture or drinking	Mostly rural
Solar thermal	Residential and industrial electricity (grid connected)	Mostly urban
Solar water heaters	Heating water	Urban and rural
Solar cookers	Cooking for homes, commercial stoves and ovens	Mostly rural
Solar dryers	Drying crops	Mostly rural
Wind turbines	Residential and industrial electricity (large grid connected), mechanical power and low voltage needs (small stand-alone)	Urban and rural
Wind pumps	Pumping water for agriculture and drinking	Mostly rural
Large hydro	Grid electricity (residential and industrial)	Mostly urban
Small hydro	Lighting and other low to medium voltage electrical needs (telecommunications etc), motive power for small industry with electric motor	Mostly rural
Geothermal	Grid electricity and large-scale heating	Urban and rural
Village scale mini-grids and solar wind hybrid systems	Lighting and other low to medium voltage electric needs such as telecommunications	Mostly rural, some peri-urban

Source: REN21, 2005b

**Table 8.** List of income generating opportunities from various energy services

Energy services	Income generating value to rural households and enterprises	Renewable energy options
Cooking	Creation of value added products that can be sold locally	Biomass (although electric appliances from wind, photovoltaic (PV) and hydro can also be used)
Heating of dwelling spaces	More comfortable working environments	Biomass (although electric appliances from wind, PV and hydro can also be used)
Irrigation	Better yields, higher value crops, greater reliability, growing during periods when market prices are higher	Biomass, wind, PV
Illumination	Increased working hours	Biomass, wind, PV, micro-hydro, geothermal
Grinding, milling, husking	Creation of value added processing from raw agricultural commodity	Biomass, wind, PV, micro-hydro
Drying, smoking (preserving with process heat)	Creation of value added product; preservation of produce to allow sale to higher value markets	Biomass, wind, PV, micro-hydro, geothermal
Refrigeration, ice-making (cold preservation)	Preservation of produce to allow sale to higher value markets	Biomass, wind, PV, micro-hydro, geothermal
Extraction	Production of refined oils or distillates from biomass, seeds or fruit	Biomass, solar thermal
Transport	Access to markets, service providers and policymakers; public transport	Biomass (biofuels)
Telecommunications (computer, telephone, internet)	Access to market news, business and financial service providers and policy processes; co-ordination of suppliers and distributors; entertainment; weather information	Biomass, wind, PV, micro-hydro, geothermal
Battery charging	Wide range of services for end users	Biomass, wind, PV, micro-hydro, geothermal

Source: REN21, 2005b

Table 8 demonstrates the increasing utility of biomass energy for a range of income generating activities. It can quickly be seen that for cooking and heating of dwelling spaces, biomass energy has significant comparative advantages over other energy sources, not least because of the higher cost of electric cooking and heating appliances. But the increasing competitiveness of biomass in providing other energy services also deserves attention. To date, renewable energy programmes have tended to focus on electricity generation, an area in which biomass energy technology has only recently become cost competitive. GNESD consider electricity as the 'starting point of development' through 'facilitating education and connection to the outside world', for example through the use of TV and radio (GNESD, 2006, p.28). They do concede that not all energy requirements (such as cooking and heating of dwelling spaces) can be met through electricity and that it can be too expensive to use electricity directly for many productive activities. Finding a way for freely available biomass energy to do more to meet other energy needs therefore merits further consideration, especially with the growing competitiveness of small-scale biomass gasifiers for electricity generation.

According to some commentators, 'artificial lighting is perhaps the most immediately beneficial form of modern energy use', which enables household and income generating activities to continue after dark, children to study longer, security and safety for women and reduces risks from burns or fires from dim kerosene lamps (Hofmann *et al.*, 2009). Although many of these benefits contribute to improved well-being, they may not necessarily lead to direct poverty alleviation in economic terms.

One concern about the use of off-grid renewable electricity generating technologies is the risk that future grid expansion could result in abandonment of those technologies. To prevent this, there needs to be prior assessment of the likelihood of communities being connected to the national grid in the future. Wherever possible agreements should be made with the grid supplier to offer compensation to owners by either buying the renewable energy system or the electricity produced, should grid extension occur (Khennas and Barnett, 2000a).

The focus of the traditional energy sector on electricity generating technologies has sidelined the potential of renewable energy to provide mechanical power, which is in some cases a more financially attractive and sustainable solution, as it can be better suited to income generating opportunities (Khennas and Barnett, 2000a). For example, wind-, solar- or hydro-powered irrigation pumps or mills can revitalise agricultural economies through increased agricultural productivity (REN21, 2005a; GNESD, 2006).

A lot of these technologies are best sited in agricultural communities where there is a suitable application for mechanical power. Nevertheless, even where such applications exist, the community may still demand electricity as the energy source due to it being associated with a more 'modern' lifestyle.

**The importance of participatory approaches in renewable energy programmes** – As with other development projects, participation and consultation of all community members at all stages of renewable energy programmes has proved essential for project sustainability, as it helps build a sense of project ownership and ensures that renewable energy technologies are well adapted to the needs of all stakeholders (Mulenga *et al.*, 2004). Too often, development practitioners have assumed what the needs of the community are, without first conducting a thorough assessment of differentiated energy needs, resulting in projects failing. Matching up energy needs with the most appropriate, affordable and reliable renewable energy supply, which is also socially and culturally acceptable, has proved vital for project success (Cherni *et al.*, 2005; Giri *et al.*, 2004). Alongside participatory activities, communication with stakeholders also needs to be strong and consistent, with responsibilities clearly distributed.



Photo: Duncan Macqueen

**Participation of women is critical for good biomass energy project design**

Ensuring extensive community involvement, adequate information and capacity building not only ensures the technology is used correctly, but also that communities can become actively involved in the supply of energy. This may be through installation, operations and maintenance, or even local manufacturing of systems. Offering income generating opportunities and fostering self-sufficiency and empowerment, makes it possible to reduce communities' dependence on external assistance, thereby enhancing project sustainability (GNESD, 2006; Khennas and Barnett, 2000a; Cherni *et al.*, 2005). In China for example, the Capacity Building Training Programme provided training to local personnel on PV/PV-hybrid Systems so that they could operate and maintain them (GTZ, undated-b).

With a lot of the research and development of renewable energy technologies occurring in OECD countries, the transfer of these technologies to developing countries has been most effective when there has been a respect and sensitivity to cultural, social and personal values. The involvement of local organisations has proved advantageous, as they may have a better understanding of local needs and be able to reduce the cultural distance between the implementing organisation and local community (Scheraga *et al.*, 2000; Gupta *et al.*, 2008).

**The central role of secure land and resource tenure for biomass energy development** – Existing biomass harvesting practices in non-OECD countries are often informal, or even illegal. One of the key ingredients to fostering community involvement in biomass energy programmes is securing the land tenure and resource rights for the areas from which biomass is sourced. As one global review states:

*'Forest tenure security is important because it is often the foundation for the social identity, personal security, and cultural survival of indigenous peoples and ethnic minorities. Forest tenure is also important for economic reasons. It has a strong role in determining who benefits or loses in the competition for economic goods and environmental services provided by forest ecosystems. Security of tenure is often a prerequisite for capital investment by government or businesses, while conversely conflicts over forest lands discourage investment and undermine sound management.'* (RRI, 2009)

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Such statements are as true for biomass energy development as they are for any other form of agricultural or forest land use. There are many ways in which land tenure and commercial biomass resource rights can be secured by forest-dependent communities. But the main legal ingredients that must be in place for such rights to be deemed 'secure' include:

- Duration – the time frame over which biomass resource rights are given needs to be sufficient to provide an incentive for communities to invest both in the growing stock, and in businesses that might sustainably use it.
- Assurance – the rights to biomass harvesting and use must be clearly prescribed, avoiding any ambiguity or distinction between 'subsistence' and 'commercial' use or between 'land' and 'forest' rights – effectively guaranteeing that communities are free to benefit from the returns of their investment without interference.
- Robustness – the rights to biomass harvesting and use must be enforced and easily defensible in a court of law. In other words they must be so prescribed and disseminated that they permeate the day-to-day practice of forest officers, transport police, customs officials and the judiciary.
- Exclusivity – there must be no overlap between the biomass resource and usage rights of communities and those of external investors or government agencies.
- Simplicity – acquiring biomass resource and usage rights should be simple, and free of excessive bureaucratic steps, lengthy documents, costly registration procedures in far-distant offices etc. (RRI, 2009).

This is not to prescribe a particular way in which biomass resource and use rights should be secured. Some countries have opted to give full private property rights to local communities (for example Brazil), others have given more conditional control over forest lands to indigenous or community groups (for example Guatemala). Yet others have opted to maintain state ownership, but grant commercial forest rights to communities conditional on certain management responsibilities (for example Nepal). It has to be possible to work out how to secure long lasting, assured, robust, exclusive and simple rights in the relevant political and cultural contexts if those rights are to deliver successful biomass enterprises (Lynn and White, 2004). An ideal end point would be equivalent to full private property rights, for example private property for a group. Communities with private property rights over biomass resources will have more secure claims over the market benefits that emerge and much stronger protection against exploitation than communities that only have access rights to state lands. In order to involve communities in developing a sustainable biomass energy industry, secure tenure and commercial rights over biomass energy crops (both tree and agricultural crops) is a fundamental necessity – an issue that we return to in Chapter 7.

**The challenge of creating an enabling policy environment** – According to the Renewable Energy Policy Network, policies and institutional frameworks for renewable energy technologies are severely lacking in the developing world (REN21, 2005a). Stable policy is particularly important for a sector in which upfront costs need to be repaid over substantial time frames. In many cases the practical potential of renewable energy technologies to meet the energy needs of citizens is overlooked in favour of centralised ‘showcase’ energy developments. This hampers the development of a range of relatively straightforward policy developments that might be tailored to particular economic, political and cultural circumstances. Examples of progressive policy measure include:

- fair subsidies across different energy types
- appropriate feed-in tariffs for grid-connected renewables,
- quota systems that encourage diversification in energy supply
- innovative financing mechanisms to encourage renewables both on and off-grid such as:
  - tax credits
  - subsidies
  - rural energy agency funds
  - soft loans
- in-country research and development support
- support for community energy operations and management capacity development,
- promotion of local production markets
- local awareness campaigns

Policy measures such as these can be found in a growing number of countries such as South Africa, where the White Paper on renewable energy implemented in 2003 aimed to scale up the proportion of renewable energy in its energy portfolio over the following decade through fiscal mechanisms, regulatory instruments, introduction of standards for better research and development and higher levels of investment in RE, and greater public awareness via educational programmes (WRI, undated). Similarly, Brazil's policies have been oriented towards the expansion of biomass energy options. Other non-OECD countries need increased awareness among policymakers of the benefits of biomass energy and clear policy measures to pursue a more sophisticated treatment of biomass energy development. Without these, developers can be discouraged by difficulties in obtaining funding or permits, long start-up times and high overhead costs (Gupta *et al.*, 2008).

Policies and frameworks should always be approached cautiously, however, since incorporating renewable energy into energy policies is often followed by ambitious renewable energy targets. For example, Mali's Action Plan for Renewable Energy Promotion was introduced to increase the percentage of renewable energy in the total primary energy supply (TPES) from less than 1 per cent in 2002 to 15 per cent in 2020 (OECD and IEA, 2009a). Although commendable, big targets risk diverting efforts towards expanding renewable energy to as many people as possible by incorporating it into the grid, without consideration for income or need, thereby preventing equitable energy distribution across a nation (REN21, 2005a). As a result, energy provision through small-scale decentralised systems to those in most need rapidly becomes neglected.

Having so far provided a general overview of renewable energy systems in the developing world, we introduce below two case studies that were both deemed successful and provide lessons used to inform our policy pointers in Chapter 7.

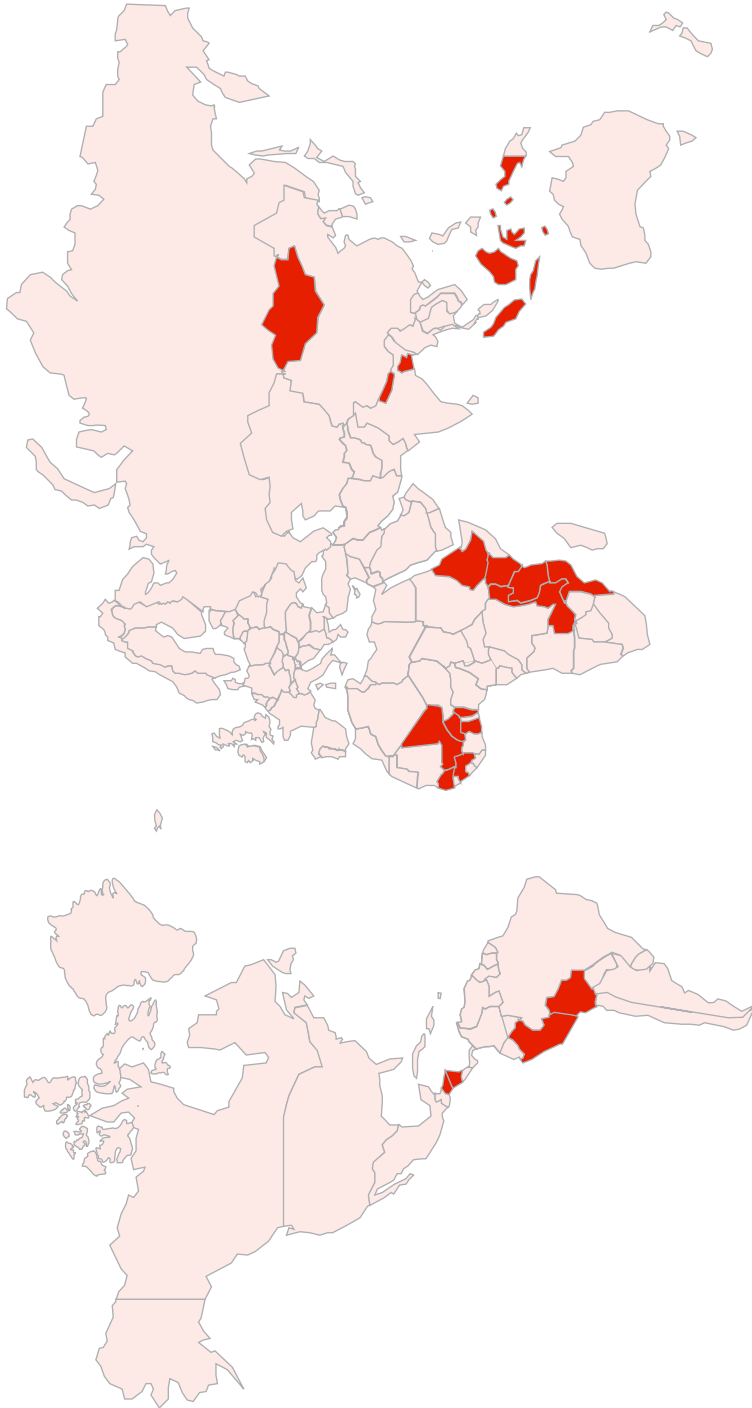
**Case study 1 The Energising Development Programme** – This first example was selected because it represents a global effort pursued by OECD country organisations.

The 'Energising Development' (EnDev) programme, a collaborative effort carried out by SenterNovem and the Gesellschaft für Technische Zusammenarbeit (GTZ), a Dutch and German organisation respectively, conducted a total of 24 activities in 21 countries (Figure 16) between 2005 and 2009, with a goal of providing improved energy sources to 5 million people by 2015 (Hofmann *et al.*, 2009).

The programme was evaluated as a success and by the end of 2008 was serving a total of 4.43 million people with an improved energy supply at the household level. This consisted mostly of improved cooking stoves but also a small proportion of central- or mini-grid connections, SHSs or micro-hydro plants. In Bangladesh alone, the programme has supported the sale of 42,500



**Figure 16.** Locations (highlighted in red) of the 21 EnDev projects



Source: Hofmann et al., 2009.

SHSs in collaboration with a local partner. The work in Ethiopia successfully used temporary subsidies for the first 100,000 stoves as a way of accelerating market growth and development. EnDev have also actively encouraged sustainable fuelwood management, by promoting reforestation activities alongside energy efficient stove projects, as seen in Nicaragua.

A lesson from this programme was the importance of co-operation with national governments. For example, with support from the Peruvian government, EnDev succeeded in promoting the widespread use of energy efficient stoves, which are being promoted through a national campaign entitled 'Half a Million Homes without Indoor Air Pollution'. The commitment to capacity building in the form of local training, also played a big part in the success of the EnDev programme.

This programme nevertheless encountered institutional and regulatory challenges, as shown in a hydro project in Rwanda in 2005. At the start, nationally standardised power-purchase agreements (PPAs) and feed-in tariffs were non-existent, making it more risky for project developers and discouraging banks from handing out loans. With great perseverance, the project has been able to obtain a standard PPA contract, paving the way for future hydro projects.

EnDev also had difficulty in demonstrating that its projects had actually contributed to poverty alleviation by reaching those below the poverty line. For example in Bangladesh, it was found that SHSs were primarily introduced into 'higher' income households because of their high cost, with the electricity consequently used for leisure purposes (such as TV or radio) rather than economically productive uses. To what extent renewable energy technologies are reaching the poor and those most in need of energy is a common concern for all renewable energy projects and one which requires more accurate poverty impact assessments.

**Case study 2 The Grameen Shakti programme** – This next example was selected because it is a particularly successful example of a smaller-scale national programme, carried out by a developing country NGO. Grameen Shakti is a local NGO involved in one of the most far-reaching renewable energy programmes, serving approximately 1 million people. Around 70 per cent of Bangladeshi households are not connected to the electricity grid and rely on kerosene for lighting (Barua, 2008). Consequently, the implementation of off-grid renewable energy systems was of particular relevance. Grameen Shakti mainly focused on PV SHSs in rural areas to meet the main demand of improved lighting, but also started to implement biogas plants and improved cooking stoves.

Table 9 summarises the three main technologies introduced by Grameen Shakti, giving an indication of the number and size of systems installed, their cost and contribution to GHG emission reductions and the goal of each by 2015. This programme is now thought to be 'the largest single provider of SHS in the world' (Barua, 2008). SHSs have often been considered too expensive for the poorest

**Table 9.** Summary of the three main technologies used in the Grameen Shakti programme

Technology used	Number of installations	Size of system	Cost
Photovoltaic solar home systems	2006: 65,000  2008: 150,000  5000 installed each month thereafter	Originally 40-120 Wp systems.  A 40 Wp system powers approx. 4 lamps for 4 hours/day, radio, phone charger and for larger systems also a TV.  For poorer households 10-20Wp systems were later introduced powering approximately 2 low-power LED lights and a radio or phone charger.	A 20Wp system: Taka (Tk) 15,000 (US\$ 178)  A 50Wp system: Tk 27,900 (US\$ 333)  3 payment options: 1. 15% deposit + loan for 85%. The loan + 6% service charge is repaid monthly over 3 years. 2. A 25% deposit + loan for 75%. The loan + 4% service charge is repaid over 2 years. 3. One lump cash sum (4% discount)
Biogas plants	3,000 between 2006 and 2008	For domestic use: 1.2m <sup>3</sup> (dung from 2 cattle) – 4.8m <sup>3</sup> (dung from 10-12 cattle) digester capacity.  For enterprise use: 6m <sup>3</sup> – 20m <sup>3</sup> digester capacity. (For 20m <sup>3</sup> plants, there has been an opportunity to generate electricity from biogas)	A 1.2m <sup>3</sup> plant: Tk 15,000 (US\$ 178) A 4.8m <sup>3</sup> plant: Tk 35,000 (US\$ 418)  A subsidy of Tk 7,000 (US\$ 77) is offered to all users. Of the balance, Grameen Shakti pay 17% + the users pay 15% down-payment + IDCOL provide a 68% loan.
Improved cooking stoves	15,000 between 2006 and 2008	The stoves have a single combustion chamber, with up to 3 holes for pots.	Tk 700-780 (US\$ 7.7-9.3) 2 payment options: 1. A 15% deposit +85% paid over 6 months with a 4% service charge. 2. Single cash payment.

Source: Barua, 2008

households, but Grammen Shakti have demonstrated flexibility in their approach, with SHS ranging between 10-120Watt Peak (a measure of the nominal power of a photovoltaic solar energy device under laboratory illumination conditions), in an attempt to meet both the modest energy services of the poorest households as well the higher energy demands of wealthier families.

The success of Grameen Shakti's expansion and diversification is attributed to the effort in providing very localised services, with projects carried out by local staff who have a better understanding of community needs, and the provision of affordable micro-credit carefully designed for specific user needs, funded by the World Bank and GEF and channelled through the Infrastructure Development Company Limited (IDCOL). Moreover, this has been complemented by careful planning of its infrastructure, dedication to high quality systems followed by a continuous after-sales service, a positive word-of-mouth marketing strategy and active community participation during planning, installation and maintenance. Grameen technology centres (GTCs) have been set up which have contributed to the training of local technicians and users, including women, which has helped create local jobs. They place the consideration of gender issues at the heart of their work; wherever possible, contracts are signed with women, since it is recognised that they are more reliant on improved energy systems as they generally spend more time in the household. To respect cultural values, daytime home visits are made by female technicians if no male household member is present.

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So far the repayment rate has been very high: 98 per cent. Subsidies were initially made available for SHSs, but were gradually cut back and eventually phased out. For the poorest households who cannot access biogas plants because of a lack of livestock, Grameen Shakti has begun to offer an innovative financing scheme, whereby households can purchase both the plant and cattle, and use the compost produced to repay the loan.

**Future priorities** – Decentralised renewable energy programmes of the sort described above have attracted much attention over the last decade. With biomass energy options now being developed at pace in both the OECD and the BRIC countries, decision makers need to have up to date knowledge to make the best energy choices for a specific region or community. The way in which energy has been branded as 'traditional' or 'modern' energy has led to biomass energy being dismissed in favour of other renewable energy technologies. This report has highlighted that the energy sources usually found at the bottom of the energy ladder, such as agricultural waste and fuelwood, can be a competitive renewable energy when used in a highly efficient manner through different technologies. Particularly where biomass is already a widely used and abundant resource, there are strong arguments in favour of building on its potential.

Despite the growing number of decentralised renewable energy projects, investment in this sector needs to be seriously scaled up, with the International Energy Agency predicting that US\$320 billion per annum will be required over the next quarter of a century to meet the energy needs of developing and middle-income countries (IEA, 2002). There has been substantial financial investment in certain technologies such as PV, but attracting new financial investment into other renewable energy technologies has faced challenges. These include the small-scale nature of decentralised renewable energy projects, longer time frames, lack of awareness among both users and financiers, high transaction costs involved with highly dispersed customers and negative perceptions of certain technologies such as biomass (REN21, 2005a; Rodgers, 2005 cited in REN21, 2005a). Better awareness among potential financiers, such as the banking sector or micro-finance institutions, could open up investment opportunities such as credit schemes, which are currently difficult to obtain in many areas (GNESD, 2007). Other options include greater private sector involvement in projects, however the extent to which this will happen will depend on the viability and cost effectiveness of the renewable energy system in question, whether any policies or frameworks exist to support it, and other factors such as economic and political stability (ARE, undated).

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As the majority of population growth over the next few decades is predicted to occur in urbanised areas, energy poverty will increasingly become an urban issue (TERI, 2008). It is unclear at this stage whether decentralised renewable energy systems in urban areas will encounter the same kind of interest as they have had in rural areas or whether the energy needs of the urban poor will continue to be met by conventional energy sources. With many urban settlements suffering from the same type of informality that characterises rural biomass energy producers there is a need to develop innovative solutions in partnership with both groups (Mulenga *et al.*, 2004). In particular, growing demand in urban areas for biomass resources requires proactive efforts to match urban demand with sustainable rural supplies. The idea that such demand is somehow 'transitional' en route to energy supplied from grid systems dominated by conventional fossil fuel is illusory. Instead, non-OECD decision makers could use the high dependence on biomass to develop more sophisticated biomass energy systems as a way of 'leap frogging' OECD countries en route to cleaner and greener economies (GNESD, 2006).

## Cost comparisons of renewable energy technologies

Despite a decline in the cost of renewable energy technologies (see Figure 14), in many cases conventional energy sources are heavily subsidised. The high initial costs of renewable energy technologies means that they might therefore remain largely unaffordable to many of the poor, who may not have access to credit on affordable terms (REN21, 2005a). The scale of the bias against renewable energy, let alone biomass energy is stark. An independent analysis by Bloomberg New Energy Finance concluded that in 2009 governments provided subsidies worth between US\$43 billion (£27bn) and US\$46 billion to renewable energy and biofuel industries, including support provided through feed-in tariffs, renewable energy credits, tax credits, cash grants and other direct subsidies (BusinessGreen, 2010). In contrast, estimates by the IEA released in June 2009 showed that US\$557 billion was spent by governments during 2008 to subsidise the fossil fuel industry (BusinessGreen, 2010).

This bias is often a major factor in non-OECD countries. For example, in 2004, the Indonesian government subsidised conventional fuel sources by US\$6.4 billion (WHO, 2005), and government subsidies worldwide were greater than \$200 billion per year during the same period (International Conference for Renewable Energies, 2004, cited in REN21, 2005a). In Malawi, electricity (primarily from hydropower stations) is sold to customers at a tariff of US 2.65 cents/kWh against an estimated actual production cost or 'long run marginal cost' in the region of US 9 cents/kWh (Government of Malawi, 2009). A potential project to set up a 100 MW biomass electricity plant to use excess wood from the major Viphya forest plantation in Malawi is not viable because the feed-in cost to the national grid is currently so low, due to the electricity subsidy. While ostensibly, the subsidy is intended to reduce urban poverty, the real subsidy is to upper-income households who consume the most power, and who receive a subsidy of around US\$830 per year. Without the electricity subsidy, electricity in Malawi would cost 143 per cent of the cost of charcoal cooking, rather than 42 per cent as is currently the case. Clearly, the development of a viable and sustainable biomass energy industry requires fairer treatment. Subsidies on conventional energy should be slowly withdrawn to better reflect their actual cost and allow a fair comparison with renewable energy technologies, but this is likely to meet some resistance.

Perhaps the best comparison between renewable energy and conventional fuels is a life-time cost of generation analysis, which was carried out recently by Ea Energy Analyses; the data from this study is plotted in the graph below (Figure 17) (Ea Energy Analyses, 2008). It should be noted that these comparisons use grid-connected costs which are useful, but should not be taken to reflect the usefulness of installing electricity in off-grid situations (where any electricity may be better than none, even if it is quite expensive to install).

For current (2010) lifetime costs (€/MWh) it is possible to compare both: a) basic costs (capital costs, fuel costs, operation and maintenance) not including externalities, and b) total costs including externalities such as the impacts on carbon emissions through estimated higher fossil fuel costs and carbon taxes. This is extremely useful, as many positive externalities from renewable energy such as reduced GHG emissions and socio-economic benefits, like time savings, increased employment opportunities, improved health and education, are rarely internalised in monetary terms in the market place, because of the difficulties in accurately quantifying them. Consequently, they are not taken into account by investors when comparing different energy options, resulting in an unfair comparison with conventional energy sources. This study however does recognise difficulties in reaching reliable and consistent values for the externalities of electricity generation between different regions, where benefits at the local level may differ extensively.

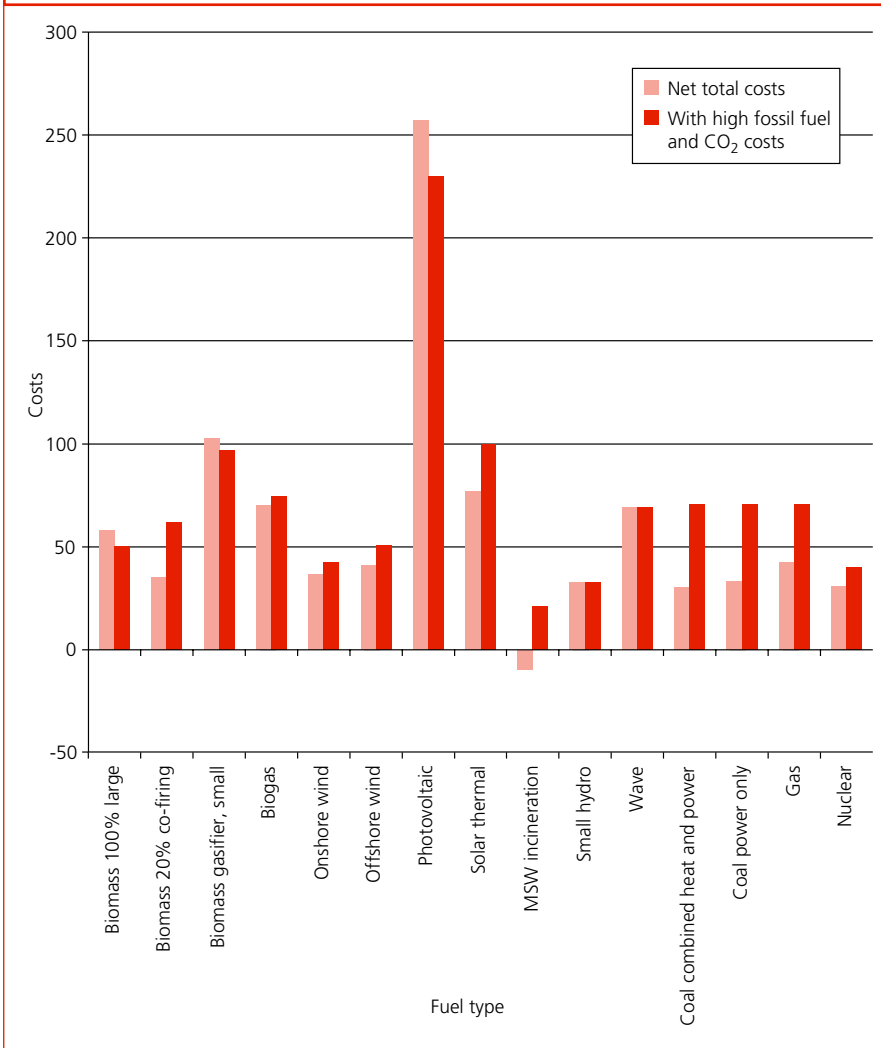


Photo: Mike Goldwater

**Sanford Housing Co-operative in London asserts that wood pellets from Brites are cheaper than gas for heating**

Figure 17 shows how co-firing biomass is competitive with conventional fossil fuel power sources such as coal or gas, other non-renewables such as nuclear, or renewable such as hydro and wind, but 100 per cent large-scale biomass electricity generation is not at current prices,. However, if externalities were to be included and fossil fuel prices and the price for CO<sub>2</sub> emissions were to rise (as is widely predicted to be the case in the future), 100 per cent large-scale biomass electricity generation would become much more competitive, especially given the political difficulties associated with nuclear and onshore wind and the limited availability of sites for small hydro. It is for this reason that many OECD countries are already granting planning permission for major developments in biomass electricity production with and without co-generation of heat.

**Figure 17.** Comparative levelised lifetime electricity costs (net) for different technologies in € per megawatt hour using current net total costs and then high fossil fuel and CO<sub>2</sub> costs

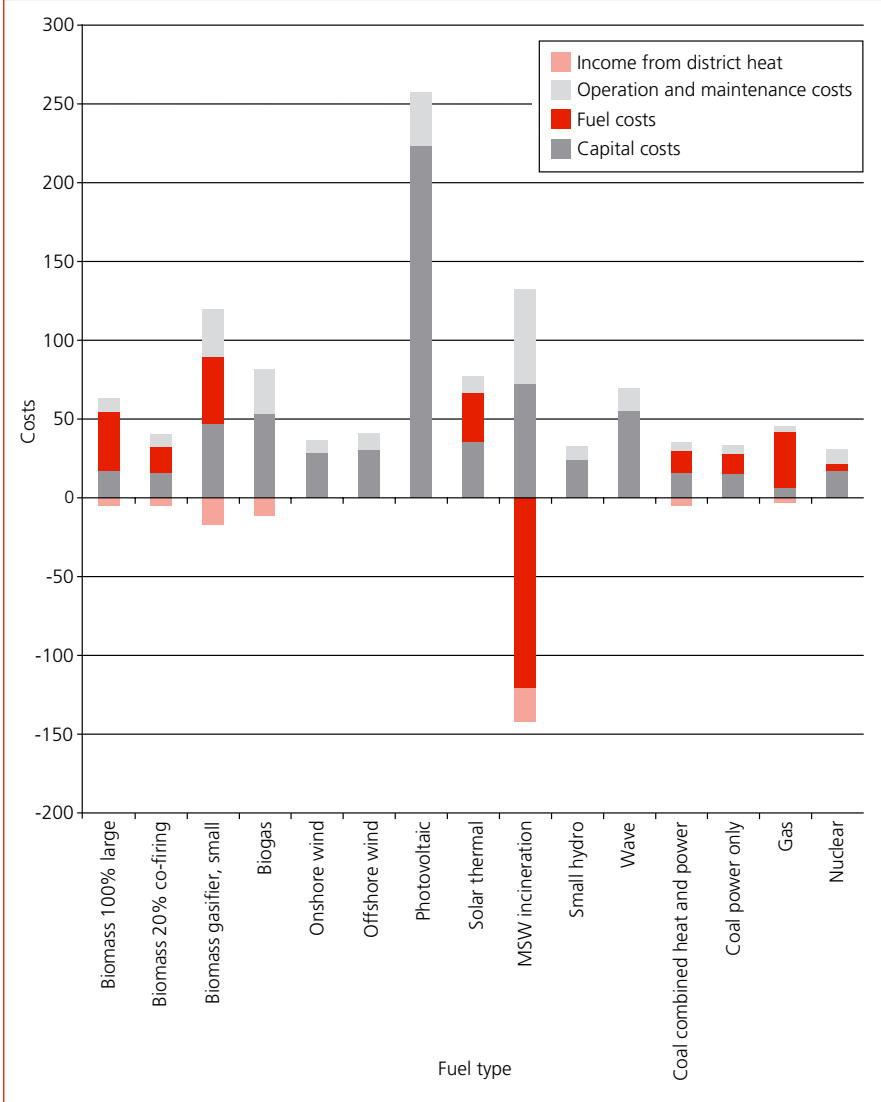


Source: Ea Energy Analyses, 2008. For full analysis of high fossil fuel and CO<sub>2</sub> costs please see source.

Looking in more detail at the component costs associated with biomass energy production, we can quickly see that it is fuel costs that make up a substantial portion of the total cost for 100 per cent large-scale biomass electricity production (Figure 18).



**Figure 18.** Breakdown of component costs of the comparative levelised lifetime electricity costs (net) for different technologies in € per megawatt hour using current costs



Source: Ea Energy Analyses, 2008

It is for this reason that many early biomass electricity generating systems have been designed in both OECD and non-OECD countries around low-cost waste products from agriculture, forestry or industrial processes, rather than around dedicated biomass plantations or biomass markets (Bhattacharya, 2002). Newer installations in countries like the UK are looking primarily to overseas pellet markets to supply biomass at more affordable prices. This is especially true when considering competition for biomass from other industries such as the pulp and paper industry. For example, in the United States the price of conifer chips delivered to pulp and paper factories was US\$70 per bone-dry ton. Yet in order to make a 12 per cent return on investment after tax, even with a federal production tax credit, the maximum price a biomass power plant could afford to pay for conifer pellets was US\$37 per bone-dry ton (Cleaves, 2009). As energy prices rise this situation will gradually shift in favour of biomass for energy – something that's driving the current large-scale development of biomass electricity plants.

While we have chosen to display current cost comparisons, it should be noted that by 2025, the cost of renewable energy technologies is predicted to fall considerably as a result of both economies of scale and increased experience of these technologies. Conversely, for conventional fuel sources (gas, coal and nuclear), the cost of power generated is hardly expected to change, making renewable energy technologies much more cost competitive in the future, with the exception of PV.

Comparing the costs of renewable energy technologies in this way is valuable, but the figures presented above stem from grid connected technologies, which can be easier to record and show a relative amount of consistency. Expansion of rural electrification through grid extension can be extremely expensive, not to mention difficult in isolated and widely dispersed rural areas, with a rapid marginal increase in cost in hard to access areas, and is thus an unattractive prospect for energy companies (AusAid, 2000; REN21, 2005a; Cherni and Preston, 2007). For currently unserved communities, off-grid renewable energy systems can be the most cost effective and practical solution in basic energy provision over the long term (AusAid, 2000; GNESD, 2007; Practical Action, 2009b).

It is difficult to make an accurate comparison of the full costs of power generated from off-grid systems, as this depends much more on local circumstances, with installation prices highly variable between regions. This is true when comparing either the same technology or one technology from another, in different regions. Just because in India decentralised biomass gasification is a competitive energy source at some capacities, does not mean that this is necessarily the case in Brazil where the technology is much less developed, or that its cost effectiveness can be directly compared to an SHS in Bangladesh. There are various reasons for this. The contribution of local labour is not always easy to value and the unstable nature of local currencies makes a direct comparison between different regions difficult. Moreover, there is a lack of consistency between 'the boundaries of the systems being compared', such as whether or not it includes wiring and connection costs (Khennas and Barnett, 2000b, p.3).

The price of a decentralised renewable energy system will also depend on the scale of production in a particular region; how far evolved a technology is; the assumptions upon which a cost analysis is based on; who is carrying out the study and their interest; whether there are any policies encouraging its development; the specific design adopted; the potential for local manufacture and production facilities available; the cost of local materials; the availability of renewable energy resources; and how isolated and dispersed a community is. In addition, the viability of a decentralised renewable energy system will be determined by how competitive it is with the local cost of petroleum-based fuel sources. Therefore the costs provided in this report for different decentralised renewable energy technologies (RETs) should not be considered conclusive, but merely an indication of current costs.

**Possible climate related financing for renewable energy** – With climate change concerns now critical at international level, commitments towards reduction of GHG emissions in both OECD and non-OECD countries provide an important opportunity for renewable energy programmes. Afforestation or reforestation for biomass energy could form part of the Clean Development Mechanism (CDM), as a way of attracting private and foreign investment although the technical accounting difficulties of forest projects have historically diminished the scale of forestry-type activities within the CDM. In addition, larger-scale grid-connected renewables are thought to be better suited to CDM financing, because of their potential to achieve much larger cuts in GHG emissions compared to off-grid renewable energy technologies, even though the latter can play a big role in improving the lives of the poor. CDM also attracts concerns over carbon credit allocation, and the fulfilments of specific environmental, technological and economic CDM criteria is likely to result in higher levels of administration and transaction costs, making it difficult for smaller projects to participate (AusAid, 2000; GNESD, 2006). Consequently, it is unlikely that small-scale decentralised renewable energy projects will form part of CDM projects in the near future. Perhaps a more realistic opportunity for smaller-scale biomass energy projects in the near future is voluntary carbon markets where their combination of environmental benefits and poverty reduction will make them attractive to voluntary buyers of carbon credits.

Additionally, if the development of renewable biomass energy is part of a strategy to maintain forest cover, biomass energy can also play a central part in national strategies for Reducing Emissions from Deforestation and Degradation (REDD). For example, in Mozambique the current unsustainable harvesting of biomass for fuelwood and charcoal has been identified as one of a number of underlying causes of deforestation. The draft National REDD Strategy in Mozambique therefore makes specific mention of the need to develop more sustainable biomass energy supply chains, especially around major urban centres where demand is highest (Government of Mozambique, 2010).

In rural areas, biomass energy provides a further advantage in terms of adapting to climate change. Biomass energy crops grown on marginal or surplus agricultural land can be more resistant to climate change than some agricultural alternatives. For example, woody crops can be chosen that are resistant to changes in rainfall or temperature, and can therefore provide economic alternatives for rural people involved in their management, harvesting, processing and trade. As such, biomass energy can also form part of a country's National Adaptation Programmes of Action (NAPAs). Those of many European countries note the potential changes in both energy consumption that might result from climate change and in some energy generation sources (for example, France's plan estimates that hydro-electric power generation will drop by 15 per cent [National Observatory for the Impacts of Global Warming, 2009]). But fewer of them make specific reference to the need to find durable renewable alternatives such as biomass. Many NAPAs in non-OECD countries such as Ethiopia or Malawi focus on reducing wood use through fuel alternatives such as biogas or more efficient stove use but at least Malawi's also recommends reforestation, more efficient use of charcoal and diversification of energy sources away from hydro-electricity (Tadege, 2007; Government of Malawi, 2006). National climate strategies continue to reject fuelwood use, seemingly forgetting that (i) trees can be planted and managed to meet fuelwood demand and (ii) that planting trees of commercial value is one of the few ways of adapting to climate change with mitigation co-benefits.

As noted in Chapters 5 and 7, one of the keys to securing the biomass growing stock (whether in agricultural or forest settings) will be land tenure security and commercial biomass resource and use rights. Without clarity over who owns the biomass (and any carbon associated with it), it will be very difficult for new climate mitigation plans such as REDD, or adaptation plans such as NAPA, to channel funds towards those responsible for harvesting biomass in return for more sustainable practice.



Photo: Mike Goldwater

**If produced sustainably, charcoal such as this on sale in Maputo, Mozambique might form part of a Low Carbon Development Strategy or National Adaptation Programme of Action**

## Political and economic obstacles in the path to sustainable biomass energy systems in non-OECD countries

Why have the potential options for producing and using biomass energy remained so poorly developed, or even criminalised, in many non-OECD countries? For example, in Malawi in 2010 there was not one instance of legal charcoal production in the entire country (Kambewa *et al.*, 2007). The answer lies at least partially in understanding the political economy of the biomass energy trade. Figure 18 shows a spectrum of possible options for biomass energy production, from

subsistence use on the left to emerging industrial options on the right marked with numbered production alternatives. While few technological barriers exist towards moving towards formal commercial and industrial expansion of biomass energy use, there are political barriers from vested interests in the political economy of the biomass energy trade that favour the status quo and these need to be addressed as a matter of urgency.



Photo: Mike Goldwater

**Timber cut and used for fuel as cowpea agriculture expands in Mecati Forest, Mozambique**

**Inappropriate policies and corruption** – In many non-OECD countries the majority of biomass production occurs on the left hand side of Figure 19 – either in production pathway 1 (domestic wood collection and use) or in production pathway 2 (informal commercial wood and charcoal production), both largely based on unmanaged forest resource use. Informal wood and charcoal production of this sort is usually formally restricted by forest policies due to its perceived threat to the forest. It rarely features in national energy policies and its scale is rarely recognised. Openshaw makes the point forcefully:

*'Thus an energy planner can talk about petroleum products accounting for 80% of the energy consumption in Tanzania, with electricity*



*accounting for the remaining 20%, when in fact biomass accounts for 80% of energy consumption and that of petroleum products and electricity 16% and 4% respectively.’ (Openshaw, 2010)*

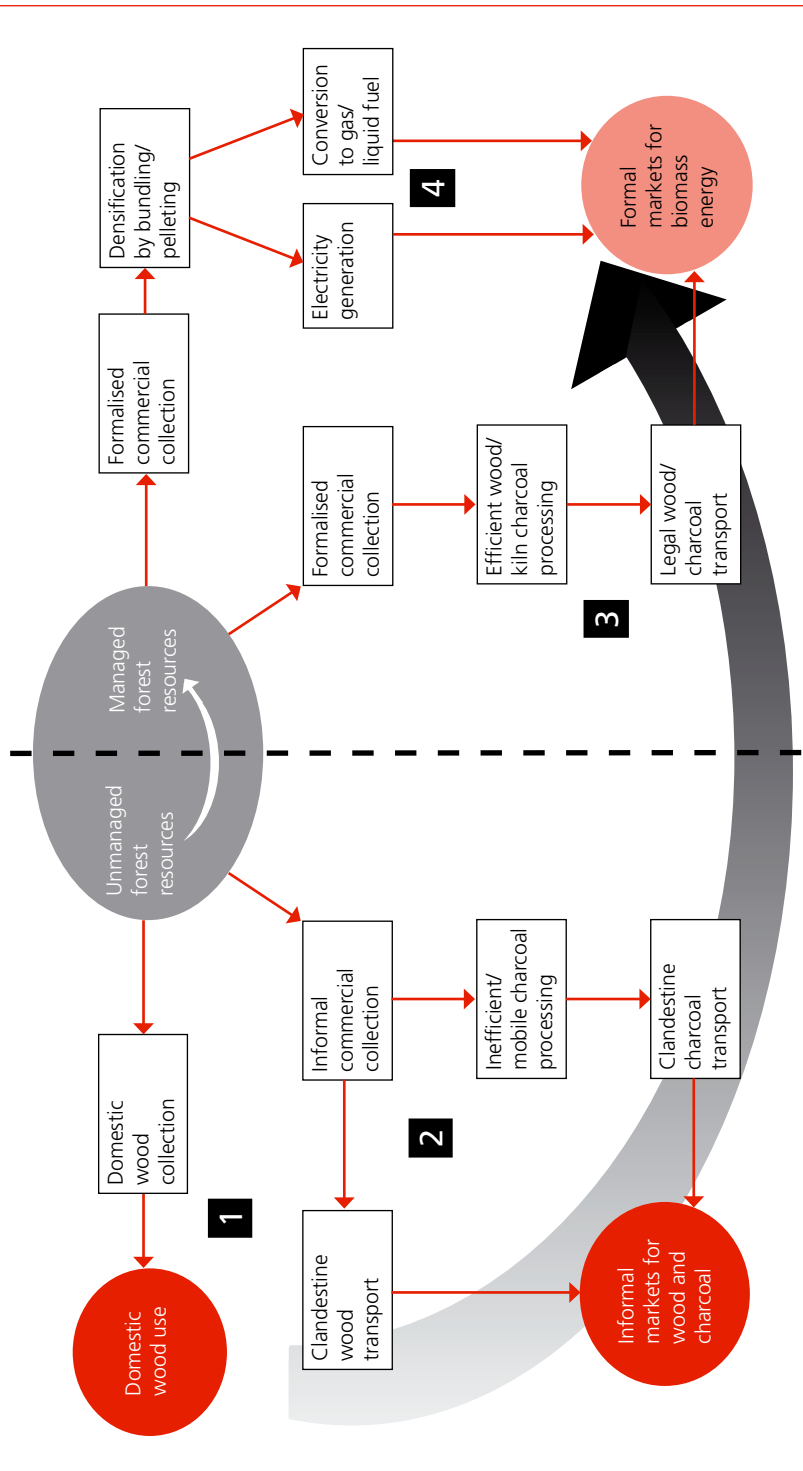
Informality and lack of information often go hand in hand. Before biomass energy was studied in some depth in Malawi, the Malawi Department of Energy assumed that rolling out electrification would eventually meet Malawi’s energy needs. But accurate data and predictions were assembled in the Malawi Biomass Energy Strategy it became abundantly clear that even the most optimistic roll out of electrification would still leave the country 82 per cent dependent on biomass in 2020 – and that with population increasing the charcoal market would double by 2023 (Government of Malawi, 2009). In short, prior energy policies that had formerly ignored biomass were for the most part irrelevant to the daily realities of most Malawians.

There are often powerful vested interests in maintaining the ignorance about the scale of biomass energy production and use and the status quo of production pathway 2. Two examples will suffice. Continuing with the Malawian example, charcoal production is the third largest industry in the country. Worth US\$41.3 million, it consumes 1.4 million cubic meters of wood per year, 60 per cent of which comes from formally protected forest reserves and National Parks and this is estimated to cause the loss of approximately 15,000 hectares of forest per year (Kambewa *et al.*, 2007). Between 12 and 20 per cent of the final value of this charcoal is being appropriated in private taxation (bribes) paid to public officials along the rural-urban supply chain. No official revenue is currently collected from the charcoal trade. With public officials among the 338 large (and well connected) charcoal traders, there is every incentive to maintain tight control of ‘illegal’ competitors and little incentive from the multiple public officials collecting bribes along the supply chain to press for a change in the system.

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Nevertheless, a combination of factors driven by increasing public awareness is leading to pressure for change in Malawi. Since 1998 the GTZ-funded Programme for Biomass Energy Conservation (ProBEC) has worked in the Mount Mulanje area promoting improved cooking stoves to increase the efficiency of wood use and drawing attention to the need for legalised and more sustainable options for charcoal production (Brinkmann, 2005). From 2004 to 2007 a detailed survey of charcoal production and use funded by USAID, the EU Improved Forest Management for Sustainable Livelihoods Programme (IFMSLP) and the Forest Governance Learning Group (FGLG) led both to the publication of a groundbreaking report called ‘Charcoal the reality’ and to a sustained campaign led by the FGLG team to press for political change (Kambewa *et al.*, 2007). In 2007, the Government of Malawi therefore requested assistance from the European Union Energy Initiative Partnership Dialogue Facility (EUEI-PDF) for the design of a national Biomass Energy Strategy (BEST) (Government of Malawi, 2009). For the first time, biomass has become a central plank in the country’s energy policy although there is still considerable work to be done to tackle the misperceptions and vested interests highlighted above.

**Figure 19.** Woody biomass energy production pathways with numbers showing desirable transition stages





In Senegal, almost all households depend on fuelwood for energy. Surveys in 1986-1987 showed that the capital Dakar, consumed 90 per cent of the country's charcoal which was supplied by 11,000 migrant woodcutters, 2900 merchants, 300 wholesalers and 2000 retail vendors through a series of forest department supply quotas. Many of the merchants and wholesalers are organised into co-operatives. In 1998 the 170 presidents and treasurers of the market's 85 co-operatives took most of the quotas with the 20 wealthiest merchants and 25 wealthiest wholesalers making on average US\$300,000 and US\$30,000 per year respectively. In comparison, an average villager received between US\$1-3.50 if village chiefs distribute charcoal revenues fairly (Ribot, 1998). Ribot details the complex webs of patronage and market monopolisation by which forest service officials and merchants control the market in favour of their own interests. Even with decentralisation nominally devolving control over charcoal production to local rural councils, those monopolising market power have found ways to maintain their grip (Ribot, 2009).

When fuelwood and charcoal production is criminalised because the land tenure, biomass resource and use rights are either undefined or defined in such a way as to outlaw widespread practice, harvesting and processing operations are driven underground. Beyond the immediate incentive for rent-seeking and corruption that this presents (described above) this is problematic on two counts. First, without secure land tenure and biomass resource and use rights there is little incentive for sustainable forest management where the harvesting activities are deemed illegal. Second, the conversion efficiency of wood to charcoal in



Photo: Duncan Macqueen

**Charcoal confiscated and resold by the Forest Department, Malawi**

mobile ditch pits or earth mound kilns (8-15 per cent) is notably less efficient than conversion in brick kilns (up to 30 per cent) or steel kilns (27-35 per cent) (Seidal, 2008). Yet no-one will invest in brick kilns if this exposes them to official sanction. Moving from informal and inefficient commercial production based on unmanaged forest resources towards formal and efficient commercial production (that is, production pathway 3 in Figure 19) therefore requires a strong commitment to sustainable biomass as a central plank of a country's energy policy with secure resource rights and appropriate incentives to encourage business investment. Two examples of a partial transition of this sort are documented below.

**Weak institutional capacity to oversee reforms** – In Tanzania, 90 per cent of energy needs are met by fuelwood. The total annual revenue generated by the charcoal sector in Dar es Salaam alone is estimated at US\$350 million or US\$650 million to the country as a whole, dwarfing the contribution of coffee and tea to the national economy (at US\$60 million and US\$45 million respectively) (Peter and Sander, 2009). Unregistered or unregulated activities in charcoal production and use lead to an estimated loss to the treasury of about US\$100 million per year. Four ministries share control of the sector which introduces some degree of confusion and overlap. Nevertheless, there are signs that the government is at least taking the issue seriously. The 2002 Forest Act provides some incentives for local communities to declare and sustainably manage their forests. The 2006 Charcoal Regulations define the establishment of district harvesting committees and plans, but without great clarity. Charcoal traders are required to register with local government authorities and pay a license fee which, while chronically under-collected, is at least nominally locally controlled (Peter and Sander, 2009).

In Niger, fuelwood and charcoal have been addressed as an energy rather than solely a forest issue (Noppen *et al.*, 2004). In the early 1970s a project known as the Guesselbodi National Forest Project had shown how better land tenure and commercial rights to harvest and sell fuelwood could provide a local incentive to restore and manage natural woodland areas. Building on this work a new project led to the first detailed survey of the country's biomass energy supply in 1984. Two follow-up projects, Energie II in 1989 and Household Energy Project in 2000 were launched with two components: a supply component that helped develop legislation for rural fuelwood markets, and a demand component focusing on urban consumption, for example improved stoves. The Government Order, catalysed by these projects in 1992, made a distinction between two types of rural fuelwood market:

- Directed markets – Areas delineated and boundaries agreed and an annual harvesting quota for deadwood but no formal management plan or use of greenwood
- Controlled markets – Detailed forest management plan drawn up with management parcels and harvesting quotas for greenwood.



Photo: Mike Goldwater

**In many countries fuelwood and charcoal production (including in kilns as above) is criminalised – despite supplying more than 80% of household energy needs**

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The new legislation also abolished the fuelwood-cutting permit and levied tax instead on the transportation of firewood, a portion of which is destined for return to local forest management funds. Between 1989 and 2002, the number of functioning rural fuelwood markets had risen from 85 to 150, with a volume increase from 75,000 to 162,000 cubic meters per annum and a total managed forest resource of 450,000 hectares out of a total of 1.2 to 2 million hectares in the targeted region. While this has not reached the targets initially set, nor completely eliminated corrupt rent seeking by officials and appropriation of taxes, the model has moved in the right direction.

As noted above, biomass energy supply based on harvesting natural forest has often encountered significant political interference due to the scale of vested commercial interests involved. This has hampered the development of sustainable biomass supply chains. Without action to legalise and make sustainable existing biomass supply future prospects for biomass energy are likely to be seriously impaired. While serious concerns over the legality and sustainability of biomass supply remain, investment in more capital intensive and technologically advanced uses of biomass energy (such as for electricity generation) is highly unlikely.

Even if corruption and vested interest can be tackled, and coherent, fair policies put in place, meeting spiralling demand for energy from a sustainable supply base will still be challenging. For example, the United Kingdom's new Department of Energy and Climate Change (DECC) was created to merge energy and climate change mitigation policy, but whether it is able to address the looming deficit in the supply of biomass within the UK, an area that is overseen by DEFRA and the Forestry Commission, is another matter.

## Policy recommendations for decision makers in non-OECD forest and energy departments

Inadequate and disjointed institutions and policies governing biomass energy are hampering the development of a vast and potentially renewable energy source that is suited both to large-scale power provision and community or household level energy solutions. This is a reality to different extents in both OECD and non-OECD countries. For example, in the UK, inconsistent and insufficient policy support has been blamed for the slow development of the sector (Korhaliller, 2010). The UK has more recently been addressing such deficiencies through the creation of stronger financial incentives (weighting biomass energy more highly in Renewable Obligation Certificates) and in 2008, the Department of Energy and Climate Change (DECC) was created, merging energy and climate change mitigation policy and within the DECC the Office of Renewable Energy Deployment (ORED) was created to carry out the commitments identified in the UK's new Renewable Energy Strategy from 2009 onwards.

In non-OECD countries, similarly inadequate policy and institutional frameworks prevail and need to be tackled. For example, in Malawi the Department of Forestry has had historic control over charcoal and fuelwood production yet Malawi's Biomass Energy Strategy has been developed under the aegis of the Department of Energy (Government of Malawi, 2009). This now provides a policy that should be conducive to reforming the sector but its implementation is still largely contingent on the adoption and implementation of the policy by the Department of Forestry. The existence of a dedicated biomass energy strategy at all is something of a rarity in non-OECD countries, despite the fact that they are more than 80 per cent dependent on biomass energy and this speaks volumes for the way in biomass has been inappropriately sidelined in national policies.

This review of biomass energy issues to inform non-OECD decision makers points towards ten key policy issues that merit further consideration.

### Biomass energy deserves...

- **a central place in strategies for national energy security** – With the proportion of biomass energy in the global primary energy mix predicted to treble over the next 40 years (see Chapter 2), policies that steer its use towards sustainability and economic development require urgent attention in many countries.
- **better understanding of its potential in green economies** – Biomass energy is readily accessible and its development can reduce national balance of payments deficits and foster local employment to reduce poverty (see Chapter 3). It can also form a central part of climate change strategies (see

below). Clear policies that foster clear biomass resource rights, sustainable management responsibilities and value chain development should be in place. Malawi's Biomass Energy Strategy is an excellent example (Government of Malawi, 2009).

- **a central role in plans to mitigate and adapt to climate change**
  - Biomass energy from renewable feedstocks when converted efficiently can be almost carbon neutral. When substituting for fossil fuels this can mean substantial reductions in carbon emissions and can therefore form part of mitigation activities. Biomass energy needs to be integrated within policies and corresponding institutional mandates that deal with voluntary carbon markets, the CDM, REDD and NAPAs (see Chapter 6).
- **comprehensive data on production and use in national energy statistics**
  - Unless the use of fuelwood and charcoal is included (accurately) in national energy statistics and planning, the data on which decisions are made will be grossly distorted. Policy will be driven by energy sub-sectors that are of piffling significance for the vast majority of citizens. Chapter 7 highlights just how significant this information gap is for some non-OECD countries.
- **clear institutional mandates for policy and sector development**
  - Historic patterns in which governance of biomass energy has largely been the preserve of Forest Departments requires reassessment. With demand for biomass energy expected to rise, there is a need to ensure the sustainable management (and expansion) of forests dedicated to energy supply. While initial efforts should be formulated around the predominant and most competitive use of biomass for cooking and domestic heat, the potential of biomass goes beyond heat. Increasingly supply-side issues must also be integrated with a suite of policies that incentivise efficient biomass conversion into desirable forms of energy (such as electricity) in close co-ordination with demand-side issues overseen by Energy Departments.
- **fair treatment alongside other energy sources** – Unless biomass is afforded equal status alongside other renewable and non-renewable energy technologies it is likely that the market will be skewed to favour options that are perceived as 'modern' but are suboptimal for both citizens and the environment. The initial paragraphs of Chapter 6 show just how inequitable the treatment of renewable energy as a whole and biomass energy in particular can be in many parts of the world.
- **secure biomass tenure based on sustainable management** – Without confidence that they will benefit commercially from the sale of their biomass, few rural communities will invest in replanting or managing natural resources towards that end. Security of tenure should receive the highest priority, not only in policies for energy security, but also policies directed towards climate change or sustainable natural resource governance more generally.

- **incentives for efficient conversion and use** – Both the comparative cost of biomass energy against energy alternatives, and the climate change impacts of biomass energy depend greatly on conversion efficiencies. There are a range of potential innovative financing mechanisms that can encourage greater efficiency of biomass energy conversion and use such as tax credits for more efficient technology, direct subsidies, rural energy funds to encourage investment in upgrading (for example to brick charcoal kilns or efficient stoves) and soft loans for the same. As described in Chapter 5 the EnDev programme's limited subsidies for the first 100,000 fuel efficient stoves in Ethiopia proved a successful way of accelerating market growth and development of the technology and its supply and distribution platform.
- **support for investment in newer biomass technologies** – In addition to the need to incentivise efficiency in existing systems, most countries also need to support investment in newer technologies such as biomass electricity generation plants. There are a variety of ways that this might be done, including grants or tax incentives. But one promising method that has been used in the OECD is to gradually ratchet up the requirements for existing energy suppliers to source energy from newer renewable technologies using green certificates or TRECs discussed in Chapter 4.
- **an active programme of research and development** – The development of new technologies and industries based upon them requires human capacity and market confidence. The only way this can be built is through active research and development. The fact that India is a global leader in the development of small-scale biomass electricity generation should come as no surprise because India invested heavily in research and development to achieve that end (see concluding paragraph of Chapter 4).

In conclusion, if biomass energy expansion follows the International Energy Agency predications, then non-OECD governments must take it seriously. Those that do may simultaneously find answers to a number of pressing issues such as rural employment and poverty reduction, incentives for sustainable forest management, climate change mitigation and adaptation and, last but not least, more secure energy supply. But these benefits will only emerge if concerted efforts are made to develop secure land and resource rights for those producing biomass, clear and accessible incentives to invest in more efficient processing technologies and policy frameworks that add value to biomass business for the ecosystem services they provide (notably reduced carbon emissions through substituting out fossil fuels).





Photo: Mike Goldwater

**Eliminating the trade in charcoal to towns such as Nampula in Mozambique would be unthinkable for poor producers and consumers alike – the question is how to make it sustainable**

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## Natural Resource Issues

Natural resources are having the life squeezed out of them. Volatile commodity prices have highlighted both the vulnerability of poor people to rapid rises in food and energy prices and the associated 'squeeze' on natural resources. Escalating competition for such resources (including biodiversity, energy, forests, food, land and water) will reshape patterns of investment, production and consumption among countries and social groups and between cities and rural areas. The Natural Resource Issues series presents peer-reviewed, easy to read material on issues that cut across these sectors. Each issue draws on original research to make conclusions that are particularly relevant for policy makers, researchers and other opinion formers in the field concerned.

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## **Bundles of energy: The case for renewable biomass energy**

Biomass energy currently makes up 10 per cent of the world's primary energy supply, but the International Energy Agency predicts that this will rise to 30 per cent by 2050. Since non-OECD countries are disproportionately dependent on biomass energy (meeting 26 per cent of their energy needs) they could capitalise on this trend. By acting now to legalise sustainable biomass value chains, such countries could create a platform for more advanced biomass energy options in the future.

When managed sustainably, biomass has significant advantages over other forms of energy in non-OECD countries, including local accessibility and energy security, low carbon emissions over long timeframes and the flexibility to be converted into heat, electricity, liquid or gas at a range of commercial scales. Per unit of energy, biomass production is also more labour intensive than other energy sources and may also hold the potential to boost rural employment and reduce poverty.

This report aims to inform forest and energy decision makers in non-OECD countries of key issues surrounding the biomass energy boom. It describes the advantages and challenges of biomass, how it compares with renewable alternatives, and how to develop policy frameworks that optimise its impact on poverty reduction, climate change mitigation and the preservation of ecosystem services. It seeks to stimulate interest in the topic and promote serious discussion about how the full potential of biomass energy can be harnessed in the service of national interests.

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