World Agroforestry Centre

# Strategy on Tree-based Energy

## Clean and Sustainable Energy for Improving the Livelihoods of Poor People

# Contents

## Abbreviations

| | |
|---|---|
| CGIAR | The Consultative Group for International Agricultural Research |
| CIFOR | Center for International Forestry Research |
| CRP | CGIAR Research Programme |
| EJ | Exajoule |
| FAO | Food and Agriculture Organization |
| FPA | Forest, Tree and Agriculture |
| GBEP | Global Bioenergy Partnership |
| ICRAF | International Centre for Research on Agroforestry |
| ICT | Information and Communications Technology |
| IDO | Intermediate Development Objective |
| IEA | International Energy Agency |
| IFPRI | International Food Policy Research Institute |
| JFK | John Fitzgerald Kennedy |
| LPG | Liquefied Petroleum Gas |
| LUC | Land Use Change |
| MDGs | Millennium Development Goals |
| PM | Particulate Matter |
| SDGs | Sustainable Development Goals |
| SE4ALL | Sustainable Energy for All |
| SLO | Strategic Level Outcomes |
| TEA | Total Energy Access |
| TERI | The Energy Research Institute |
| UN | United Nations |
| UNDP | United Nations Development Programme |

## Executive summary

Lack of access to energy is one of the causes of poor people being caught in poverty traps. Energy is needed to help people to escape from poverty, and access to modern sources of energy is needed for people to engage in productive activities that allow them to improve their livelihoods, earn incomes and move onto a path of true sustainable  development. About 2.7 billion people worldwide depend upon solid fuel for their basic energy needs for cooking and heating, and most of that energy is obtained from woody biomass. Although there are important global and national policies to give poor people greater access to modern sources of energy, currently demands for firewood are increasing and urbanization and increased incomes are leading to an increase in the use of charcoal for cooking. All of this comes at a great social and economic cost. Women and children spend hours a day in the drudgery of collecting firewood for cooking. Lack of adequate energy for cooking can lead to uncooked and indigestible food being eaten and unsafe materials such as plastics being burned. Charcoal production is devastating large areas of remaining dry forests. People's health suffers from exposure to indoor air pollution. Farms are unable to mechanize and improve productivity, and communities are stuck without energy options to engage in productive enterprises.

This strategy lays out an approach to developing various kinds of bioenergy derived principally from trees to, first of all, improve the provision of basic energy needs, and then to provide modern sources of bioenergy for reducing poverty and improving livelihoods and income generation. These aims will be achieved while protecting environments and ecosystems services and improving the management of productive landscapes. Adopting greater use of sustainable bioenergy bioenergy will contribute to climate change mitigation. Achieving the aims of the strategy will involve: improving access to firewood using agroforestry systems and improving the efficiency of cooking; making charcoal production and use sustainable; developing liquid biofuels; generating electricity from woody biomass; implementing sustainable integrated energy-food systems; ensuring the biodiversity of biofuel production by employing agroforestry systems; mitigating greenhouse gas emissions by shifting to renewable bioenergy and improved landscape management; and, ensuring a strong policy and institutional basis for change.

The strategy employs a “Research in Development” approach that will require ICRAF to work closely with other CGIAR Centers, a range of research and academic institutions and also with development partners.

## Background and justification

Energy and poverty

Global energy production in 2013 stood at 13,634 Mt (million tonnes oil equivalent, or 570 EJ) [1]. Energy consumption in developing countries is very low, and countries with low Human Development Indices tend to have the lowest per capita energy consumption rates[1] (Figure 1).

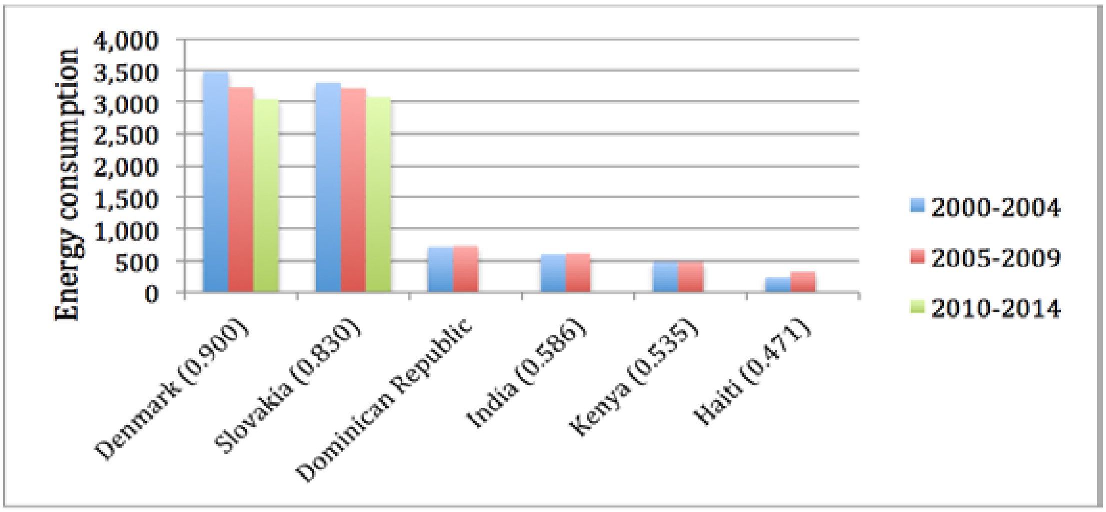
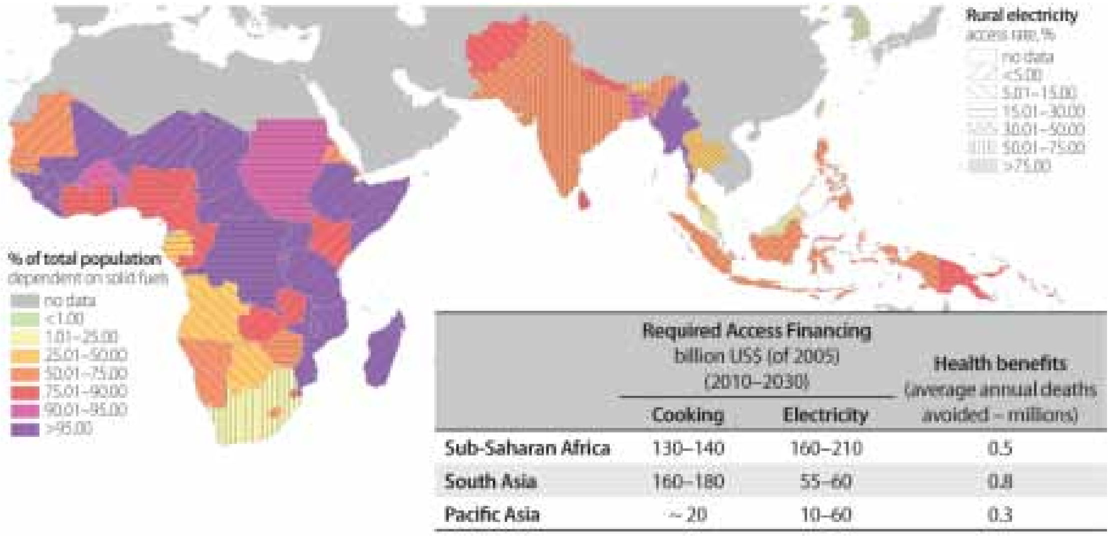



**Figure 1:** Energy consumption (kilo tons oil equivalent) per capita in selected countries with different Human Development Indices – indicated in brackets (sources World Bank and UNDP)[2]




| | Required Access Financing billion US$ (of 2005) (2010–2030) | | Health benefits (average annual deaths avoided – millions) |
|---|---|---|---|
| | Cooking | Electricity | |
| Sub-Saharan Africa | 130–140 | 160–210 | 0.5 |
| South Asia | 160–180 | 55–60 | 0.8 |
| Pacific Asia | ~ 20 | 10–60 | 0.3 |

**Figure 2:** Populations without access to clean cooking fuels and electricity in sub-Saharan Africa and Southeast Asia. Note colours represent % of population dependent on solid fuels **[2]**

[1] http://data.worldbank.org/indicator/EG.USE.PCAP.KG.OE/countries

[2] http://www.unic.org.in/items/Publications_HumanDevelopmentReport2014.pdf

Large proportions of the populations of countries in sub-Saharan Africa and Southeast Asia live in energy poverty, defined as lack of access to electricity or clean cooking facilities (Figure 2)

Lack of access to energy leaves people in severe poverty traps. The concept of Total Energy Access (TEA) has been used to set lower acceptable limits for access to energy (Table 1).

| Energy service | | Minimum standard |
|---|---|---|
| Lighting | 1.1 | 300 lumens for a minimum of 4 hours per night at household level |
| Cooking and water heating | 2.1 | 1kg woodfuel or 0.3kg charcoal or 0.04kg LPG or 0.2 litres of kerosene per day |
| | 2.2 | Minimum efficiency of improved solid fuel stoves to be 40% greater than a three stone fire in terms of fuel use |
| | 2.3 | Annual mean concentrations of particulate matter (PM2.5)<10$\mu$g/m$^3$ |
| Space heating | 3.1 | Minimum daytime indoor temperature 18˚C |
| Cooling | 4.1 | Households can extend the life of perishable products by a minimum of 50% over that allowed by ambient storage |
| | 4.2 | Maximum apparent indoor temperature 30˚C |
| Information and communications | 5.1 | People can communicate electronic information from their households |
| | 5.3 | People can access electronic media relevant to their lives and livelihoods in their household |

**Table 1:** Minimum Total Energy Access standards **[3]**

The minimum standards set for energy access ensure only basic energy supplies for cooking, keeping warm, household lighting and access to information while minimizing the effects of indoor air pollution. Much greater amounts of energy are needed to energize development. Enterprises including agriculture, rural industries and modern businesses need energy for transport, pumping, processing, manufacturing, and information and communications technology. Escaping poverty, improving livelihoods and improving incomes are all dependent upon access to adequate energy in the right place and when it is needed. Unfortunately, over 2.7 billion people in the world have few prospects of getting access to the energy they need [4].

## Sources of energy

The main sources of energy available globally are

- Fossil fuels
  - ✓ Coal
  - ✓ Oil
  - ✓ Natural gas
  - ✓ Petroleum gas

- Nuclear energy

- Renewables
  - ✓ Wind power
  - ✓ Photovoltaics
  - ✓ Geothermal
  - ✓ Hydropower

  - ✓ Bioenergy
    - o Ethanol
    - o Biodiesel
    - o Second and third generation biofuels
    - o Biomass

*Fossil fuels* are the greatest contributors to climate change, and will run out. They are non-renewable and finite. A looming shortage of oil has led to further exploration and exploitation in places where extraction was previously thought to be uneconomical. This has delayed "peak oil" (the time when access to oil stocks will start to decline), but only for so long. Hydraulic fracturing ("fracking") has provided a novel source of natural gas that is increasingly being exploited, but this will eventually be limited by problems of access to gas-bearing rock and transport costs. Safety concerns may also limit fracking. "Peak Oil" (a web-based forum that states that it explores the issue of hydrocarbon depletion) claims that the peak of production of hydrocarbons occurred in 2011 (Figure 3).

*[At the time of writing this strategy the price of crude oil had crashed from over $100 per barrel to below $50. If maintained this would make exploration for new sources of oil and gas unprofitable, but, in the short term at least, make investment in bioenergy less attractive as long as petrol, oil and gas were cheap. Predictions for prices for 12 months ahead varied greatly. Some commentators predicted that long term prices would fall even more; others predicted that prices would recover to their former level. Mainstream predictions were that prices would stay low for some months and then rise to $70 - $80 per barrel. If and when the international economy recovered fully, prices could rise even more].*

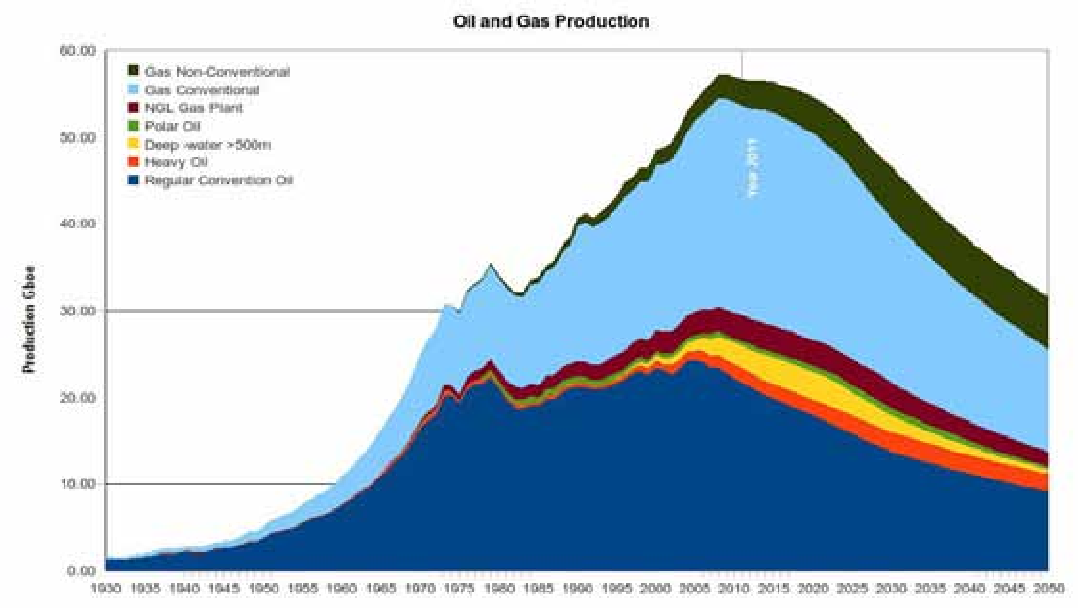



**Figure 3:** Oil and gas production 1930-2050

Coal is in good supply, but increasingly believed to be too dirty and climate damaging to be used in greater quantities, unless expensive methods of carbon capture can be developed and used [5]. Given the undesirable effects of fossil fuels on atmospheric warming, the only valid long-term policy is to eliminate them. The problem is what to replace them with.

*Nuclear power* has the potential to provide abundant power without emissions during electricity generation. Full life-cycle costings that take into account emissions during construction and decommissioning provide more realistic estimates of greenhouse gas emissions, which are nevertheless low over the long term. At present fears about the safety of nuclear plants linked with the problems of storing nuclear waste are militating against much expansion of nuclear power. The International Energy Authority cut its predicted 2015 global nuclear capacity prediction by 10% compared with a year earlier [6]. There seems to be little chance that nuclear-sourced energy will be available to the energy poor in the near or medium future.

A number of *renewable sources of energy* are being developed, used and improved. Solar power derived from photovoltaic panels is increasing in efficiency and becoming cheaper. Solar panels have the obvious disadvantage that they only work during the day and when there is plenty of sun. They do not deliver much energy per unit area, so their utility is limited, but much more efficient solar converters are under development [7]. Improvements in battery technology to store solar power until required will make photovoltaics more useful. Wind turbines are improving and becoming cheaper. They generate useful amounts of electricity, but only work when it is windy, so cannot be relied upon as the only source of power. Hydropower also has the potential to provide large amounts of energy and apparently without harmful emissions. However, large scale hydropower plants are expensive to build and their construction generates significant emissions.

A reasonable conclusion is that although all of the energy sources discussed above will continue to be used, in the long run fossil fuel use will have to reduce, which will leave a major gap in energy budgets. *Bioenergy* has the potential to fill that gap along with other renewable sources of energy. In 2008, bioenergy provided about 10% of the world's primary energy supply [8]. According to the International Energy Agency (IEA) "[Bioenergy] plays a crucial role in many developing countries, where it provides basic energy for cooking and space heating, but often at the price of severe health and environmental impacts. The deployment of advanced biomass cook stoves, clean fuels and additional off-grid biomass electricity supply in developing countries are key measures to improve the current situation and achieve universal access to clean energy facilities by 2030"[4]. In addition, the IEA predicts that biofuels could provide up to 27% of the world's transport fuel by 2050 [9]. The World Energy Council [10] predicts that world annual primary energy demand by 2050 will be in the range of 600 to 1000 EJ, and based on reviews of studies carried out in 2008 [11] estimates that global demand for bioenergy could be 250EJ/year.

The first generation of large scale bioenergy production was based on ethanol from sugar cane. Brazil was the pioneer country, and by 2013 global ethanol production for fuel (from ethanol, cereals and other sources) stood at over 88 billion liters per year, with 57% produced in the USA, 27% in Brazil, 6% in Europe, 3% in China, 2% in India and only 3% in the rest of the world[5]. Based on Brazil's success there should scope for increasing ethanol production in many developing countries. Tree crops might be used to provide feedstock for the distillation of ethanol as a fuel. One potential tree is *Nypa fructans*, the Nipa Palm, which is widely

[3]http://peakoil.com/what-is-peak-oil

[4]http://www.iea.org/topics/renewables/subtopics/bioenergy/

[5]http://ethanolrfa.org/pages/World-Fuel-Ethanol-Production

distributed among mangrove forests of Southeast Asia and produces an abundant sap from which ethanol can be produced at a rate of 6,480-10,224 L/hectare/year. This is less than sugarcane, but more than many other ethanol feedstocks [12].

Biodiesel can be produced from a number of plants by extracting the liquid part of fruits and seeds, usually by cold pressing. Different biodiesel fuels lend themselves to either large-scale or small-sale processing. Processing begins with mechanical cold pressing to extract the oil followed by filtration or sedimentation of suspended solids. Sometimes pre-preparation, such as roasting the seeds, is necessary. Where small-scale pressing is practiced, the extracted oil can sometimes be used directly to drive diesel engines, or used as a fuel for cooking or lighting [13]. Alternatively, biodiesel can be processed at larger scale (with fruits or seeds sourced either from small-scale or large-scale producers) where oils are put through an industrial process of transesterification that produces a refined fuel and removes a number of undesirable contaminants [14]. A solid cake typically representing 10% of the original fruit or seed is left after processing, which depending on the toxicity and palatability of the original crop, can be used for animal feed or returned to the soil [15].

Biodiesel can also be produced from animal fats, typically obtained from abattoir waste. So-called second generation biofuels are under development. They depend upon thermal or biochemical treatment to break down the lingo-cellulosic components of plants into materials that can be fermented to produce ethanol. Third generation biofuels are still at the research stage. They are based on algae that have the potential to produce a range of liquid fuels.

A number of valuable liquid biofuels can be obtained from tree species. Oil palm fruit, coconut fruit and *Jatropha curcas* are sources of biodiesel. Oil palm has proven potential for transformation into a number of products and fuels, including biodiesel [16]. The original expected potential of Jatropha has not been realized, mainly because although it grows on marginal land, it yields poorly and gives poor economic returns under smallholder management [17]. However, industrial interest in Jatropha as a biofuel crop remains high, but based on improved cultivars and good management rather than the essentially wild varieties promoted as development opportunities for small-scale farmers. *Pongamia pinnata* has been identified as a tree with potential for biodiesel production [18] but while commercial trials are under way, the crop is at an early stage of development.

There are many other trees around the world with oilseed or other production potential for either biodiesel of ethanol. In India, an estimated 300 species of oil bearing trees are available. Some of these species have been shown to be valuable feedstock for biofuel such as Pongamia (*Pongamia pinnata)*, neem (*Azadirachta indica)*, mahua (*Madhuca indica / Madhuka logifolia) and Simarouba (Simarouba glauca)*. In Africa, *Croton megalocarpus* is being harvested for biofuels, and the pulp left over from processing is finding a role as a soil amendment material in local agriculture. *Copiaifera langsdorfii* (diesel tree, from South America), and *Xanthoceras sorbifolium* (from China) are among many other trees with biofuel potential.

Poor people around the world are dependent upon biomass energy, mainly derived from trees. Woodfuel provides more that 80% of primary energy in Sub-Saharan Africa, where the *per capita* consumption of wood for energy is almost 0.7 $m^3$/person/year. The global average is about 0.28 $m^3$/person/year [19]. Sub-Saharan Africa is therefore the region of the world that uses most woodfuel overall (see Table 2).

| Region | Sub-region | Woodfuel production (1,000 m³) |
|---|---|---|
| Africa | Central Africa | 110,621 |
| | East Africa | 200,699 |
| | North Africa | 47,792 |
| | Southern Africa | 58,469 |
| | West Africa | 171,091 |
| | **Total Africa** | **588,673** |
| Latin America and Caribbean | Caribbean | 5,120 |
| | Central America | 40,195 |
| | South America | 195,856 |
| | **Total Latin America and Carib-bean** | **241,171** |
| | East Asia | 216,621 |
| | South Asia | 382,745 |
| | South East Asia | 185,903 |
| | Oceania | 12,838 |
| | **Total Asia and Pacific** | **794,104** |

**Table 2:** Woodfuel production by region, 2006 **[20]**.

Although there are major global initiatives to ensure that poor people have access to "modern" energy sources (including some renewables, but also focusing on kerosene, liquefied petroleum gas and other fossil fuels) there are convincing reasons to believe that woodfuels in the form of firewood and charcoal will remain important sources of fuel for the poor of the world for many years to come, especially in Sub-Saharan Africa and South Asia (see Figures 4 and 5).

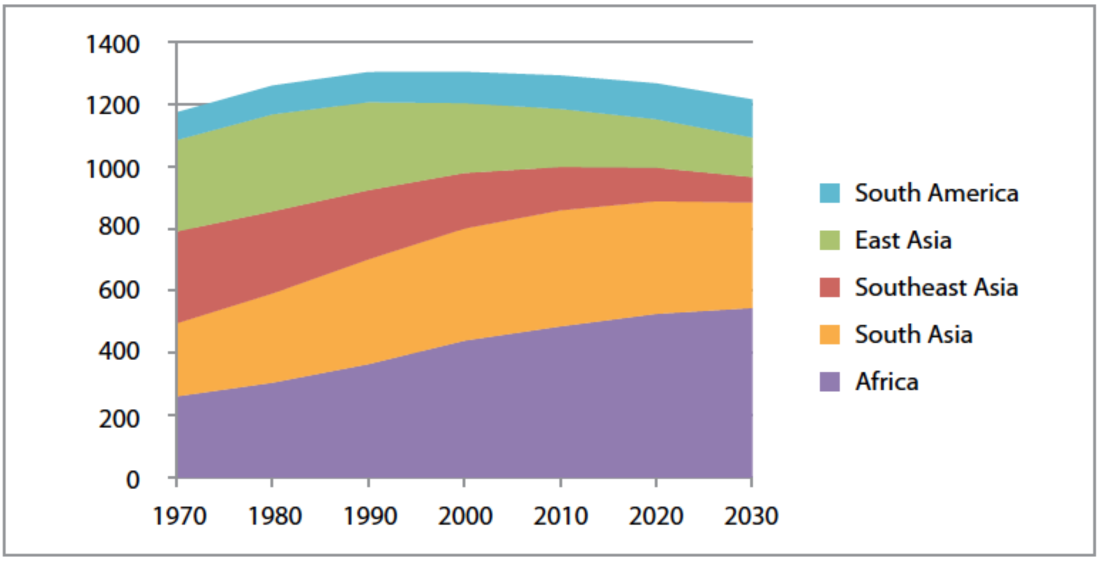



**Figure 4:** Projection of fuelwood consumption in developing regions (million m3) **[21]**

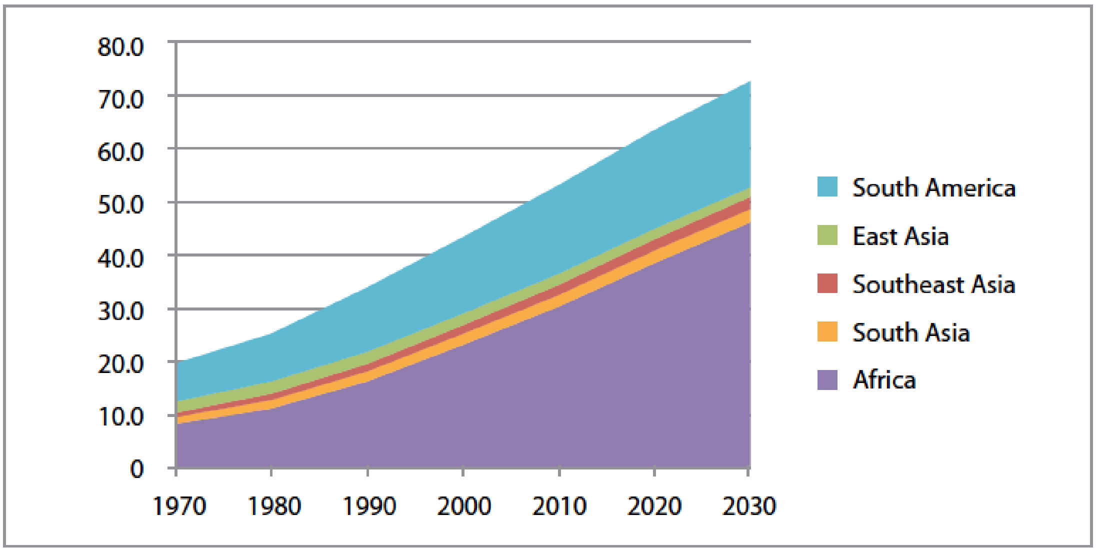



**Figure 5:** Projection of charcoal consumption in developing regions (million tonnes) **[21]**

Apart from the important role of tree-based biomass in providing energy in developing regions, trees also have the potential to provide “modern energy”. In particular, woody biomass can be used to produce electricity at scales suitable for community use. The Energy and Resources Institute (TERI) in India has developed downdraft biomass gasifier generation systems in the range of 3.5 kWe - 100 kWe (kilowatt of electricity)[6]. A number of practical community-level applications of biomass power generation have been installed around the world, for example in India, Sri Lanka, Cambodia, Mali and developed countries [22]. There are several agroforestry-based tree-livestock systems operating in Sri Lanka where *Gliricidia sepium* is grown in association with coconuts and used for livestock fodder and for generating electricity[7].

## Summary

Poor people depend upon firewood and charcoal to provide their energy. Despite great efforts to introduce modern sources of energy, it is evident that poor people will continue to use firewood and charcoal for several decades. Firewood meets the basic needs of poor people for cooking (and sometimes for heating), while charcoal is mainly used in the growing cities of developing countries. However, if people are to be lifted out of poverty, they need access to energy for enterprises, including agriculture, rural and urban businesses, computers and mobile telephones. Trees have the potential to provide energy for these enterprises in the form of biofuels and electricity. Providing firewood and charcoal sustainably will require considerable research (as will be discussed later in this strategy), and much research and technology development will be needed to understand and achieve the full potentials of liquid biofuels and biomass-fueled electricity generation. There is therefore full justification for ICRAF, working with partners, to add bioenergy to its research portfolio.

[6]http://www.eai.in/club/users/Shweta/blogs/7411

[7]http://archives.dailynews.lk/2012/01/13/fea03.asp

## Bioenergy and the CGIAR

Bioenergy has never featured strongly in the CGIAR portfolio of projects. Although the project document for the CGIAR Research Programme on Forests, Trees and Agriculture (FTA) refers throughout to energy, in practice little research on bioenergy has been done under this CRP. The CGIAR focuses on: the improvement of its mandate crops; livestock; water resources; fish, farming systems; biodiversity; ecology; forest policy; and, agroforestry. The creation of the CGIAR was driven by a growing global concern about the threat of famine and the original CGIAR was focused on breakthroughs in plant breeding that made it possible to greatly increase crop production. The subsequent expansion of the CGIAR and its various changes of focus mirrored changes in policies of the international community at large, especially a growing environmental consciousness and recognition of the importance to humanity of healthy ecosystems. Currently the System Level Objectives of the CGIAR are: *Reduced Rural Poverty, Improved Food Security, Improved Nutrition and Health* and *Sustainably Managed Natural Resources*. The breadth of these objectives reflects an understanding that reducing poverty and achieving food security requires a multi-disciplinary approach including health and nutrition and management of the resource base that people depend upon.

The CGIAR Results Framework was currently under revision at the time of writing this strategy, and at the same time the United Nations was coordinating an exercise to reach global agreement on a set of Sustainable Development Goals (SDGs) to replace the Millennium Development Goals (MDGs). There was good alignment between the objectives of the CGIAR and the SDGs (as they stood at the time of writing this policy) with their references to ending hunger, achieving food security, improving nutrition and promoting sustainable agriculture. The SDGs referred to "food production systems", and this language was echoed in the current revision of the CGIAR Results Framework.

The SDGs include an important addition to the MDGs. Energy has often been referred to as the "lost MDG". This has been corrected in the SDGs, which at the time of writing this strategy included Goal number 7 "Ensure access to affordable, reliable and modern energy for all". Although the goal does not refer explicitly to sustainability, one of its targets is "increase substantially the share of renewable energy in the global energy mix by 2030". The need for energy to be sustainable is also recognized by the United Nations at the highest level in the Secretary General's *Sustainable Energy for All* initiative (SE4ALL). There is scope for CGIAR centers to branch out into bioenergy research, including but not restricted to FTA.

Global policies on energy have certain internal inconsistencies. While the need for sustainability is generally recognized, policies (as epitomized by the SDGs and SE4ALL) pay even greater attention to the rights of all to access to "modern" sources of energy. This is the result of decades-long discussions about whether it is fair to require developing countries and emerging economies to forgo the benefits of coal, gas and oil even though developed countries grew their economies by using fossil fuels and still burn prodigious amounts. As a result, the energy policies of all developing countries are based on the use of fossil fuels, with much less attention to renewables. The conundrum for ICRAF and the CGIAR is whether enabling greater use of firewood and charcoal is consistent with efforts to achieve sustainability and whether liquid biofuels and woody biomass can provide "modern" sources of energy. *This strategy will set out to establish that the use of firewood and charcoal by poor people will persist for many years, and that it can be made sustainable, and that woody biomass can, indeed, provide "modern" energy*.

## A theory of change

The theory of change for ICRAF's involvement in bioenergy research is based on the following testable assumptions.

1. Energy poverty is one cause of poverty traps that prevent people from escaping poverty, improving their livelihoods and increasing their incomes. Providing energy can raise people out of poverty and contribute to the improvement of their livelihoods and their adoption of strategies that lead to greater incomes. The poorest people in the world are dependent upon biomass for cooking and heating. Collecting firewood is drudgery that takes up the time when women could be caring for children and doing more productive work [23]. Children occupied in collecting firewood should be at school [23]. Lack of access to firewood can prevent food being properly cooked or people may burn potentially dangerous materials [24] [25]. There are severe health hazards caused by burning firewood indoors [26] [27].

2. The demand for charcoal in urban centers is high and growing. Charcoal production is unsustainable and causes loss of woody vegetative cover, especially in semi-arid parts of the world [28]. Making charcoal sustainable will require science and technology (maintaining stocks of the right trees and improving the efficiency of production and use [29]) and improvement of the effectiveness of the value chain.

3. Trees can provide "modern" energy. Biofuels have the potential to provide energy for enterprises, including agriculture, rural economic activities and modern businesses. Farm productivity in developing countries is highly constrained by low farm sizes [30] and lack of mechanization. Increased use of tractors has been the greatest contributor to improved farm productivity in Asia and Southeast Asia [31]. Off-grid electricity can be provided at community levels through using biomass to generate electricity

4. There are perceived and real issues relating to the sustainability of tree production for bioenergy. There could be competition between energy production and food production [32] and large-scale bioenergy production has often been associated with plantation production systems that have damaged biodiversity, competed with other land uses and destroyed ecosystems services. On the other hand, bioenergy has the potential to be renewable and contribute to climate change mitigation.

5. A cross-cutting assumption, affecting all of the above, is that global and national policies are often unfriendly to bioenergy and will need reform.

The theory of change is therefore based on an **overall aspirational goal**:

> *To ensure improved access to energy among poor people in order to reduce poverty, improve food and nutritional security, improve livelihoods and increase incomes while maintaining the integrity of ecosystems and contributing to climate change mitigation.*

The goal will be achieved through the achievement of the objectives and outcomes in Table 3.

| Objective | Outcome |
|---|---|
| Improve access to adequate firewood to ensure that basic needs for cooking and heating are met, while protecting people from the effects of indoor air pollution. | Increased firewood stocks from woodlots and agroforestry systems using short rotation production systems.<br><br>Livelihoods improved be reducing the diversion of time and effort to firewood collection and the creation of more time for productive and educational activities<br><br>Income from firewood sales.<br><br>Improved efficiency of cooking, and reduced mortality and morbidity, through improved cookstoves, ventilated cooking areas and provision of the most suitable and less toxic species of firewood.<br><br>Improved food and nutritional security as a result of better cooking capabilities. |
| Develop sustainable charcoal systems. | Increased firewood stocks from woodlots and agroforestry systems using short rotation production systems.<br><br>Improved efficiency of charcoal production through improved technology.<br><br>Increased incomes of charcoal producers, and greater incentives to grow trees for charcoal in agroforestry systems.<br><br>Improved effectiveness of charcoal value chains with better benefits for participants and consumers after eliminating rent seeking.<br><br>Increased efficiency of charcoal stoves. |
| Identify trees with potential for biofuel production and develop systems to produce market and utilize liquid biofuels (along with other sources of biofuel). | The potential of tree species for biofuel production tested and quantified.<br><br>Incomes increased through collection systems for collecting, bulking and transporting fruits, seeds and sap for biofuel processing.<br><br>Local processing facilities in place and incomes improved through using locally-produced biodiesel for transport, pumping, processing, lighting and maintaining ICT services.<br><br>Trees planted for biofuel production as elements in agroforestry systems and a domestication programme under way to improve the most promising species.<br><br>Value chains in place to provide incentives for rural people to collect or grow biofuel materials for the local market or to supply large scale producers. |
| Develop biomass electricity systems for off-grid community use. | Communities meeting their economic and social needs for electrical power by utilizing biomass from sustainable short rotation woodlots or trees from agroforestry systems, as well as using other locally available kinds of biomass. |

| | |
|---|---|
| Develop integrated fuel-food systems. | Plans in place and being implemented for sustainable food-fuel systems that include on-farm agroforestry systems and landscape-level integrated systems following "land sharing" or "land sparing" principles as appropriate.<br><br>Optimized farming systems for reducing food and nutritional security and providing income earning opportunities. |
| Ensure adequate diversity of plants and biodiversity in bioenergy production systems and the conservation of ecosystems services. | Agroforestry introduced into bioenergy production systems, especially biofuel plantations.<br><br>Provisioning and regulating ecosystems services recognized and protected. |
| Contribute to climate change mitigation through an increase in sustainable bioenergy use. | A greater understanding of and quantification of the benefits of bioenergy use for climate change mitigation.<br><br>Policies and plans modified to optimize mitigation benefits from increased bioenergy use. |
| Review bioenergy-related policies, institutions, laws, regulations and licensing procedures and make necessary reforms. | Institutions recognize the potential values and advantages of bioenergy.<br><br>National and local policies include bioenergy in energy planning and capacity development.<br><br>Legal frameworks provide incentives to increase bioenergy in available energy mixes. |

**Table 3:** Objectives and outcomes

The theory of change leads to a programme structured to produce outputs as described in Table 4.

| **Goal** | *To ensure improved access to energy among poor people in order to reduce poverty, improve food & nutritional security, improve livelihoods and increase income while maintaining the integrity of ecosystems and contributing to climate change mitigation* | | | |
|---|---|---|---|---|
| | **Poverty** | **Incomes** | **Ecosystems** | **Climate change** |
| **Firewood** | Short rotation wood production<br><br>Improved stoves<br><br>Best/suitablespecies selected | Wood sales<br><br>Energy saving interms of bills | Sustainable wood production, replacing collection | Agroforestry systems put in place to provide optimal conditions for renewable use of the resource |
| **Charcoal** | Informal nature of charcoal production regularized | Increased income | Increased exploitation of agroforestry systems, greater efficiency through use of briquettes from various feedstocks and less environmental destruction | Improved efficiency |
| **Biofuels** | Involvement of poor rural population in collecting and growing biofuel feedstocks | Sale of biofuel feedstocks<br><br>Biofuel feedstock trading and processing<br><br>Power available for productive purposes | Trees for biofuels grown in agroforestry systems<br><br>Biofuel expeller returned to soil | Biofuels substitute for fossil fuels |
| **Electricity** | Lighting available for enterprises, studying, security and charging telephones and computers | Electrical power available for productive purposes<br><br>Lighting lengthens business day | Short rotation wood production provides fuel without endangering forests | Biofuels substitute for fossil fuels |
| **Integrated fuel-food systems** | Food and energy requirements satisfied | Biofuel feedstocks available for sale in addition to conventional agricultural products | Optimization of energy and food production in productive ecosystems | Fuel-food systems contribute to climate-smart agriculture |
| **Diversity** | Ecosystems services in place to support small-scale agricultural production | Risk of deterioration of productive landscapes reduced Risks of monoculture | Provisioning and servicing ecosystems services conserved | Diverse productive landscapes reduce emissions |
| **Policy** | Basic energy needs recognized in national energy policies | Productive enterprises benefit from better energy policies. Reduced expenditure (in terms of work and cash) on energy | Bioenergy policy integrated into ecosystems conservation policies | Bioenergy policies contribute to development of climate-smart agriculture |

**Table 4:** Outputs of the Programme

## A theory of place

It is recognized that the one solution to the sustainable bioenergy will not work in all landscapes and solutions will be different based on agricultural systems such as small holder *vs* large scale agriculture.  Therefore, ICRAF intends to develop and use a model as below:

Intensive large scale plantations: Characterized by large scale monoculture operations of a domesticated tree and annual species

Integrated Food-energy systems: Characterized by integration of trees in agricultural land escapes (agroforestry) for improving local energy

Agricultural 'waste' & 2nd generation systems: Based on the use of agricultural and other waste to generate a stream of energy options

Extensive systems: This is the system where existing trees in forests or other landscapes are extracted to generate local energy options

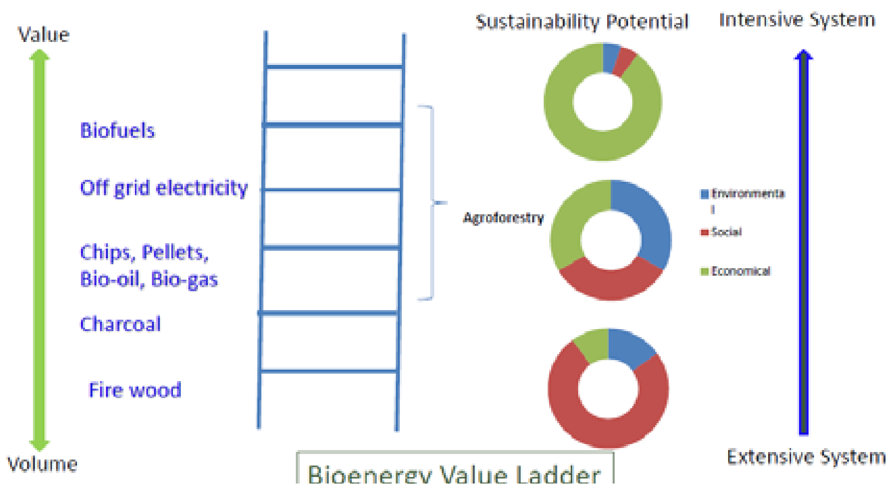



**Figure 6:** Bioenergy Value Ladder

## Gender aspects

The provision of energy is one of the most gender relevant issues in development. As discussed in this document, poor women and children bear the greatest burden in providing and using energy for the family. Apart from the work and time involved in collecting firewood, women and children suffer most from indoor air pollution and are tasked with cooking for the family. Any lack of firewood leads to a reduction in the quantity and nutritional quality of the family's food. Women often also bear the greatest burden in growing the family's staple foods, and suffer when ecosystems services suffer, for example when land degradation or land use change affects water availability to crops. Women are likely to be the greatest beneficiaries of this strategy when it leads to better access to energy and the conservation of productive landscapes. In addition, women are usually responsible for processing crops for consumption, especially pounding grains to de-hull them and make flour. The availability of energy to run grinders and mills will make this task much easier. Women usually put the most time into looking after children, and availability of light will make study easier after dark and energy for tasks carried out by children will free them to go to school.

However, this strategy aims at going beyond simply reducing women's burdens to actively maximizing opportunities for women to participate in income-earning activities, whether it is growing cash crops or engaging in profitable enterprises. All activities planned under the strategy will be guided by that principle and will ensure that any benefits generated are shared by men and women from different ages, ethnic and socio-economic backgrounds.

Access to energy alone will not open up opportunities for women to become involved in businesses or other enterprises. It will be vital that research involves understanding the differential needs, capacities, knowledge and priorities of men and women, from different backgrounds and that these different social groups are involved in defining the scope and focus of projects. Equally, the design and implementation of projects should observe potential gender concerns and collect information from both men and women and analyze this data to make visible potential variations and inequalities.

The experience of UNDP's "Multi-functional Platform" programme can point the way to energy interventions that particularly benefit women. A multi-functional platform is basically a diesel engine, often mounted in a shipping container, designed so that a number of implements can be mounted on the engine at different times of the day. The implements can be run directly from the engine, or by electricity generated by the engine. They include pumps, mills, oil presses, battery chargers and soldering and welding equipment. Batteries can provide lighting, or lights can be run directly from a generator. Multi-functional platforms were designed with women particularly in mind, and women have participated fully in defining the jobs they need done and the implements they need. Women have been responsible for the management of the platforms, including when certain services will be made available during the day. As an example of the success of providing energy, shea butter production in a village in Mali increased from 3kg to 10kg per day[8].

The reduction on drudgery resulting from the "Multi-functional Platform" allowed women to pursue other more profitable activities and freed time to dedicate to their well-being and personal development. Studies showed that in villages in Mali that have adopted MFP girl school attendance rates have increased, as well as participation of women in the local economy. The programme has also generated dynamics for structural transformation in giving a new value to tasks traditionally performed by women as unpaid obligations to men[9].

[8]http://www.undp.org/content/dam/aplaws/publication/en/publications/environment-energy/www-ee-library/sustainable-energy/reducing-rural-poverty-through-increased-access-to-energy-services-mpp-in-mali/Reducing%20Rural%20Poverty_2004.pdf

[9]Benjamin K. Sovacool*, Shannon Clarke, Katie Johnson, Meredith Crafton, Jay Eidsness, David Zoppo (2012). The energy-enterprise-gender nexus: Lessons from the Multifunctional Platform (MFP) in Mali. Renewable Energy, 50 pp. 115–125

## Rationale for ICRAF to undertake the Programme

The strategy is well aligned with the CGIAR Strategic Results Framework Table 5.

| Intermediate Development objective | Sub-Intermediate Development Objective | Contribution of Bioenergy Strategy |
|---|---|---|
| **SLO 1. Reduced poverty** | | |
| **IDO 1 – Increased resilience of the poor** | Sub IDO 1.1 - Improved enabling environment | Recognition of energy security as an important issue |
| | Sub IDO 1.3 – Reduced production risk | Diversified crop/energy systems |
| **IDO 2 – Enhanced smallholder market access** | Sub IDO 2.1 – Improved enabling environment | Improved fuelwood/charcoal policies |
| **IDO 3 – Increased agricultural profitability** | Sub IDO 3.1 – Diversified enterprise opportunities | Options for growing energy crops and integrated energy-food systems |
| | Sum IDO 3.1 – Diversified enterprise opportunities | Access to energy opens new enterprise possibilities |
| | SUB IDO 3.2 – Increased livelihood opportunities | Options to participate in value chains for energy feedstocks |
| | Sub IDO 3.3 – Increased value capture by smallholders | Access to bioenergy markets |
| **IDO 4 – Increased agricultural productivity** | Sub IDO 4.3 – Enhanced genetical potential | Domestication and improvement of trees for increased biofuel production and rate of biomass growth |
| | Sub IDO 4.4 – Genetic diversity of agricultural and natural landscapes increased and conservation of biodiversity ensured | Productive landscapes managed for balanced production of food and energy with protection of ecosystems services and biodiversity |
| **SLO 2. Improved food and nutritional security for health** | | |
| **IDO 5 – Increased dietary quality** | Sub IDO 5.4 – Increased efficacy of nutrition practices in food systems | Assured supply energy for cooking |
| **SLO 3. Improved natural resources systems and ecosystems services** | | |
| **IDO 8 – Improved sustainability of agricultural and aquatic production systems** | Sub IDO 8.1 – Improved policies for sustainable intensification of production | Planning for bioenergy production maximizes tree diversity |
| | Sub IDO 8.3 – Agriculture intensified through sustainable management of water, pests and soils | Residual cake from biofuel processing available as soil amendment |
| **IDO 9 – Enhanced conservation of water, soils, forests and biodiversity in agricultural landscapes** | Sub IDO 9.2 – Enhanced conservation of critical resources and habitats | Managed food-fuel trade-offs. Forest-sourced bioenergy |
| | Sub IDO 9.3 – More sustainable management by, and improved livelihoods of people dependent on forest resources | |
| **IDO 10 – Enhanced resilience of vulnerable areas and restoration of degraded land** | Sub IDO 10.2 – Above- and below-ground biomass increased | Increased incentives to produce biomass |

**Table 5:** CGIAR Strategic Results Framework: contribution of bioenergy strategy to Intermediate Development Objectives

Of all of the CGIAR centers, ICRAF is best placed to manage this strategy. The strategy specifically focuses on tree-based energy, and especially on how energy can be supplied by trees under agroforestry systems and without imposing greater pressure on forested ecosystems. This matches ICRAF's mandate, experience and skills.

## Partnerships

The strategy covers disciplines and topics that ICRAF is not well set-up to cover on its own. This strategy will need to become a model within the CGIAR of a research in development initiative that is carried out through partnerships with research and development partners. The themes where strong partners will be needed include:

*Multilateral Institutions*

- GBEP: sustainability indicators
- SE4All: energy efficiency
- FAO: methodologies
- GIZ: case studies

*CGIAR Centers*

- Forests policy (CIFOR)
- Crop-based biofuels (several centers)
- Integrating energy production into food policies (IFPRI)

*Research institutions*

- Energy options analysis
- Life cycle energy production efficiency
- Life cycle greenhouse gas emissions analysis
- Biofuels processing
- Electricity generation from biomass
- Improved cooking technologies

*Development institutions*

- Energy policy
- Value chains
- Institutional strengthening
- Capacity development
- Finance

*Private Partners*

- Value chains
- Business models
- Markets
- Technology

## Programme implementation

It is initially proposed that the strategy be established as a cross-Science Domain activity, under the direction of a coordinator who will be accountable to the Deputy Director of Research.

## Perceived Risks and Cost of Inaction

"There are risks and costs to inaction. But they are far less than the long range risks of comfortable inaction – JFK"

Bioenergy is a gateway to many areas of development such as livelihoods, quality of life of women and children, women health, energy security, food production, nutrition security, abetment of greenhouse Gas emissions to name a few. It is also linked to the development of alternative land use systems for the long term sustainable development. We realize that there are far more positives with the strategy than the perceived risks. The perceived risks may come from engaging in liquid biofuel areas especially with monoculture approaches (in an intenstive system) with food crops that may lead to land use change. Several negative impacts of first generation biofuels have been identified, and efforts are underway to address these challenges. Biofuels derived from food crops are blamed for the food crisis in 2008 because of diversion of food crops for biofuel production. However, if managed sustainably and produced via non-food or multiple use feed stocks biofuels can potentially be a part of efforts to mitigate climate change risks [34] [35] [36]. To address the issue of LUC and the 'fuel vs. food' debate, it is important to avoid displacing commercially attractive food crops from their most suited agro-ecologies and to use marginal land unfit for agriculture or surplus land suitable for production of second generation biofuels. It is now very clear that current biofuel crops (food crops) are not sustainable. Moreover, in current form and implementation such as monoculture in agricultural landscapes, they have limitations in their ability to achieve targets for oil product substitution, climate change mitigation, and more importantly economic growth of smallholder farmers. However, if non-food or multiple use crops especially well proven and locally adapted tree species are considered and smart farming systems are developed that can address food security and livelihoods of smallholder farmers and can provide local energy for agriculture production, it has the potential to address both mitigation and adaptation aspects of climate change risks. Trees on farms or outside forests will be the basis of future biofuels; smart agroforestry systems will be crucial to addressing the challenges faced by first generation biofuels. Clearly cost of inaction for ICRAF overweighs the perceived risks.

As per FAO Director General Graziano da Silva “It is important not to forget that biofuel emerged with strength as an alternative energy source because of the need to mitigate fossil fuel production and greenhouse gases – and that need has not changed”[10]. He also emphasized the need to rethink the whole area as ‘food and fuel’ and not as food vs fuel.

[10] http://www.fao.org/news/story/it/item/275009/icode/

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