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# BGjournal

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**Exploring energy gardens**  
**Botanic gardens and biofuels**



**BGCI**

*Plants for the Planet*

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**Cover Photo:** Child carrying firewood in Gorkha, Nepal  
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# EDITORIAL:

## BIOENERGY AND THE ROLE OF BOTANIC GARDENS

In this issue of BGjournal we address one of the most significant global challenges – the provision of alternative energy. With the impacts of climate change ever more evident the search for reduced carbon energy sources and the drive for sustainable energy use become increasingly urgent. Plants are a key part of the solution. Preparing this compilation of articles has been thought-provoking. BGCI's main aim is to secure plant diversity for people and the planet. We need to consider biodiversity conservation within the context of tackling broader environmental sustainability. Linking plant conservation with bigger societal concerns should help to increase the relevance and understanding of our work and that of the global network of botanic gardens.



*Hopea chinensis* in Yunnan, China (BGCI)

The use of plant material for energy use dates back nearly 800,000 years. In many parts of the world fuelwood remains the main source of domestic energy as noted by David Nkwanga in his article on waste-to-energy in Uganda. David succinctly describes the connections between plant conservation, livelihoods and energy use and presents one practical solution being developed at Nature Palace Botanic Garden. It is apparent that botanic gardens are well-placed to carry out research on “growing energy” and to inform and engage the public. As Beverley Glover points out in the article considering the potential use of algae in a low carbon economy, Cambridge University Botanic Garden's project illustrates *“how different scientists can work together to explore the full potential of green organisms to tackle global concerns, an ethos that underlies much of our work at the Garden.”*

Jon Lovett, Professor of Global Change at the University of Leeds, provided the stimulus for this special issue of BGjournal, which is sponsored by ESRC and DfID under the Development Frontiers Research Fund. Jon recognises the huge value of the global botanic garden network in disseminating new ideas. He envisages a global network of demonstration energy gardens showing how local plants can be used to provide locally appropriate energy sources – an exciting idea! Working with Trudi Entwistle, Jon promoted a design competition for landscape architecture students at Leeds Metropolitan University. I was delighted to judge the designs last year and I think you will agree the results of the students' work as shown in this issue are outstanding!

Botanic gardens are already highlighting the importance of biofuels and biomass in the provision of energy as highlighted, by Beatrix Schlarb-Ridley, author of the Cambridge University Botanic Garden's article and by Terry Marie Hastings writing about Bioenergy Day collaboration between the University of Georgia, Athens and the State Botanical Garden. The Xishuangbanna Botanic Garden has an energy garden as a permanent display. This is described by Zeng-Fu Xu, Jianxiang Hu, Tianping Huang, and Jin Chen in their article.

There are major controversies relating to the growing of energy plants on an industrial scale, as noted by Jon Lovett and botanic gardens will help inform the debate. I hope that you enjoy this issue of BGjournal and we welcome your feedback.

During 2014, BGCI staff will be working hard to promote the role of botanic gardens in the implementation of the Global Strategy for Plant Conservation. This is a key part of our Five Year Plan which is outlined on p. 30-31. We are delighted to welcome Professor Stephen Blackmore, one of the early proponents of the GSPC, as the new Chair of the Board of BGCI and we look forward greatly to the benefits of his wisdom, experience and guidance.

**Sara Oldfield**  
Secretary General, BGCI

# NEPAL ENERGY GARDEN PROJECT: EXPLORING ENERGY GARDENS AS A SOURCE FOR LOCAL FUEL PRODUCTION

The School of Geography at the University of Leeds is collaborating with BGCI to develop Energy Gardens for small-scale farmers in Nepal. The project aims to find a solution to controversies surrounding the use of biomass and biofuels for energy production by using indigenous plant species grown in field edges or as shade. By harnessing the power of plants through technological innovation, we hope to transform the lives of small-scale farmers. The research team includes geographers, sociologists, economists, botanists and engineers from the UK, Nepal and India.

*Green terraced fields in the Helambu Himalayas, Nepal (Steve Estvanik / Shutterstock.com)*



Mountain landscape of Nepal (Rosliak Oleksandr / Shutterstock.com)

## Background

Plants capture energy from the sun through photosynthesis and store it in the form of vegetative growth. This growth takes a wide variety of forms from woody to soft tissues, and can be quite complex chemically including sugars, oils and other products. Plants are thus ideal sources of renewable energy. This energy is released through burning wood and other forms of biomass, but more recently, plant products such as vegetable oils and sugars have been used to create biofuels for running internal combustion engines. Indeed the first diesel engine, built by Dr Rudolf Diesel in 1885, included peanut oil in its fuel.

**“Energy Gardens grow plants for energy production. Fuel wood is one garden product, and new technologies enable biomass to be burnt more efficiently. Plants can also be converted into biofuel or gas.”**

Biofuels and biomass are important sources of renewable energy, yet implementation of bioenergy programmes has attracted considerable controversy. The greatly increased use of biofuels that resulted from national and international policies encouraging their use coupled with a sharp rise in the costs of fossil fuels, gave rise to considerable public concern. Biofuels have been implicated in ‘food for fuel’ controversies, food price increases,

loss of access to land through ‘land grabbing’ and loss of biodiversity through conversion of natural ecosystems to biofuel plantations such as for palm oil.

While the development of large-scale industrial biomass and biofuel production has an important role to play in sustainable energy provision, the real strengths of using plants for energy is that they can be grown in a wide variety of situations and thousands of different species can be used. This allows the opportunity to create ‘Energy Gardens’ for small scale farms using indigenous species grown in association with food crops, for example in field bunds or as shade. We believe that, in combination with new technologies, it is possible to establish community-based biofuel production systems that overcome environmental and social concerns about biofuels.

## Developing new models

The Energy Garden concept originates from an idea developed by the Hassan Biofuels Park in India (See p. 23) which has developed an entirely new concept in biofuel production. The system is based on the use of indigenous oil seed plants which are grown in field bunds and as shade trees for local biofuel production, and the fuel produced is then used for powering village-level engines such as irrigation pumps or for transport. The model draws on a

successful milk-marketing model for linking communities and enhancing cooperation. In this way it completely rethinks the provision of liquid fuel away from the centralized mass-production and distribution system currently in place for the provision of fossil-fuels,

Not only is the Hassan project working with several thousand farmers in both wet and semi-arid ecological zones, but it has also had a substantial influence on State and National biofuel policies leading to a shift towards pro-poor community-based biofuel production away from large-scale ‘land-grabbing’ and ecological transformation projects.

The key features incorporated into the Hassan approach are:

- If the biofuel value chain is integrated with small-scale farming then it augments ecological sustainability.
- It is also pro-poor because it is part of the livelihoods of the smaller producers, who own about 70% of agricultural land in India.
- All categories of farmers can be involved, both small and large.
- By planting an appropriate range of oil-producing species production can be maintained throughout the seasons thereby enhancing employment during the ‘lean’ seasons.



Agricultural landscape in South East Asia (View Apart / Shutterstock.com)



*Cooking with fuel wood Annapurna, Nepal (Paul Prescott / Shutterstock.com)*

- Food planting area (and hence food security) is not affected if planting is on field margins, on bunds or as shade-trees.
- If cake from the oil extracting process is used as fertilizer then nutrients are returned to the food production system.
- Water-foot print is not a problem because the biofuel plants will receive water from crop irrigation.
- Selection of local species helps maintain biodiversity and ecological integrity, for example there are about 300 oil producing native species that could be used in India.
- Planting of trees can help with soil conservation.

The situation in Nepal is sufficiently similar to that in India for the concept to be transferred. However, some important questions remain to be tackled by the project.

Policy frameworks require rethinking at government level and implementation remains a problem even if the policies are revised. Old policy decisions need to be removed in order to enable new policy thinking to help farmers in the best way; and bureaucracy remains an obstacle. At a higher level, national biofuel policies can control imported biofuels, leading to the question of whether it is possible to reconcile trade restrictions with international law. At a local level, incentives to growers need to be assured through pricing, a stable market and favourable taxation. For example, can small-scale farmers be

protected from cheaper imported products without infringing trade agreements? Moreover, whilst the small farmer model can provide some critical local needs, such as irrigation pump fuel, it will not be sufficient for more general provision of transport fuels. Finally there is also the question of transfer and uptake of new technologies.

### **The project objectives**

The objectives of this project are therefore fourfold.

Firstly to investigate the institutional economics of energy biomass and biofuel production from local to national and global scales. Biomass energy is of course traditionally used at a local level, but a range of institutions, such as community forest management, govern

access rights. With a shift to different energy production systems, such as biofuel, novel biomass utilisation and reed-bed sanitation, different modes of institutional mechanisms will emerge. These new institutions will be positioned in both national and global energy and climate change institutional frameworks.

The second objective is to undertake a technical assessment of resources and conversion routes. This would include availability of under-utilised biomass and whether it can be used for a particular biofuel; the potential of indigenous



*Child carrying firewood in Gorkha, Nepal (Zzvet/Shutterstock.com)*



*Maize can be grown for food or as a source of biofuel (Soo Hee Kim / Shutterstock.com)*

species for energy production; opportunities for turning weeds and invasive species into energy; sanitation, reed bed systems and energy; biochar production for improving crop yields and soil quality; and technical innovations for biomass conversion and energy production.

The third objective is to combine the institutional and technical analyses to devise socio-economic incentives and structures for community cooperation and building long-enduring institutions around energy production and technology uptake. This would include uptake and transfer of technologies in households and communities and the role of energy as a factor of production in micro-enterprises.

The fourth objective is dissemination and knowledge transfer. The nature of the project partnership ensures both north-south and south-south cooperation. The involvement of BGCI opens the possibility of a novel dissemination route through display and pilot projects in an international network of botanic gardens.

## Conclusions

The negative publicity associated with biofuels and biomass as a form of renewable energy has resulted from a particular type of policy. Instead of focusing on the benefits of decentralised energy production for local use, and researching the means to achieve that, biofuel production has aimed to mimic the scale and distribution systems of fossil fuels. This has resulted in problems with land ownership, use of alien species, and carbon-intensive methods of production. The Energy Garden concept is simple: grow fuel *in situ* using indigenous plants. Harnessing the sun's energy in this way side steps all the problems, and brings direct benefits to the people who need it most.

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*A range of fast-growing grass species can be grown for biomass (BGCI)*

### Project partners:

Asia Network for Sustainable Agriculture and Bioresources (ANSAB) <http://www.ansab.org/>  
Ethnobotanical Society of Nepal (ESON) <http://www.eson.org.np/>  
Practical Action Nepal [http://practicalaction.org/wherewework\\_nepal](http://practicalaction.org/wherewework_nepal)  
Botanic Gardens Conservation International (BGCI) <http://www.bgci.org/>  
Hassan Biofuels Park <http://biofuelpark.org/>  
Feminist Dalit Organization (FEDO) <http://www.fedonepal.org>

### Centre for Doctoral Training in Bioenergy

The University of Leeds, UK has launched a Centre for Doctoral Training in Bioenergy funded by the UK's Engineering and Physical Sciences Research Council that will host 50 EPSRC funded PhD studentships over the next five years (2014-2019) for UK and EU students. The centre will tackle the interdisciplinary challenges of sustainable bioenergy through research on technical performance, cost effectiveness, sustainable production, food security and biodiversity. More information is available at: <http://www.engineering.leeds.ac.uk/bioenergy/>



# BIOENERGY DAY @ UGA

The University of Georgia, Athens (UGA) teamed up with the State Botanical Garden to celebrate National Bioenergy Day – October 17th.



(University of Georgia)

## Introduction

More than 200 Athens seventh-graders (12-13 years old) experienced first-hand how wood and other organic materials generate energy at the first Bioenergy Day @ UGA, held at the State Botanical Garden of Georgia last October.

Through hands-on activities, the students learned some of the “big concepts” associated with alternative energy sources: What are alternative energy sources? Why is using alternative energy sources for fuel important for the environment? Why is it important to find non-food source items with which to create alternative energy?



(University of Georgia)

And why are non-food source alternative energy sources so hard for scientists to develop?

But just as important, they had fun learning it, thanks to an effort that brought the State Botanical Garden of Georgia together with UGA bioenergy researchers and engineers, and teachers and outreach specialists from across the University of Georgia and beyond.

## University of Georgia: Serving the State

The University of Georgia, a land-grant and sea-grant university with statewide commitments and responsibilities is the state’s oldest, most comprehensive and most diversified institution of higher education. Its motto, “*to teach, to serve and to inquire into the nature of things,*” reflects the University’s integral and



*(Leslie Boby)*

unique role in the conservation and enhancement of the state's and nation's intellectual, cultural, and environmental heritage.

Located in Athens, Georgia (Clarke County), about 65 miles northeast of downtown Atlanta, UGA is composed of 17 schools and colleges, with a combined undergraduate and graduate enrollment of almost 35,000 students.

The State Botanical Garden of Georgia is a 313-acre preserve set aside by the University of Georgia in 1968 for the study and enjoyment of plants and nature. Located three miles south of the campus, it is a living laboratory, providing the public of all ages and UGA faculty and students opportunities for learning, research, recreation and events. The Garden contains a number of specialized (theme) gardens and collections, over five miles of nature trails, and four major facilities including a tropical conservatory.

Education at the garden enriches the curricula of schools across the state of Georgia. The garden conducts instructional field trips that address state standards, lends materials for self-guided children's programs, provides resources and programming for science nights, and hosts afterschool activities with an environmental focus. A variety of professional development opportunities for educators are offered throughout the year.

### **Whistle-stop tour sparks interest**

Planning for the event began late in August when members of the UGA Bioenergy Systems Research Institute (BSRI) were contacted by Southern Regional Extension Forestry about an upcoming "roadshow" featuring Auburn University's mobile biomass gasifier.

The mobile unit, which contains a gasifier, gas filtration unit, and a combined heat and power generation unit, converts wood chips, switchgrass and other agricultural byproducts to energy – on the spot. Over the past few years, it has travelled more than 20,000 miles to demonstrate gasification and power generation from biofuels, coordinated by Southeast Partnership for Integrated Biomass Supply Systems (IBSS), a partnership of UGA, the University of Tennessee Center for Renewable Carbon, and Auburn University, in Alabama.

The gasifier was scheduled to do a Whistlestop Tour across the Southeast – including a stop in Athens – to promote biofuels during the first week October. The tour was timed to coincide with the

first-ever National Bioenergy Day on October 17, when events in many states were planned to raise awareness about biomass and the role bioenergy plays in communities. Their goal: to bring audiences, ideally people who benefit from bioenergy, to biomass facilities to witness firsthand what goes on.

### **Tapping into UGA bioenergy expertise**

The planned gasifier stop in Athens soon transformed into Bioenergy Day @ UGA, an event that tapped into the deep bioenergy expertise of the University of Georgia, which is reflected in the membership of the Bioenergy Systems Research Institute, or BSRI. The goal of BSRI is to provide infrastructure,



*(University of Georgia)*

**“ 24 events in 13 states across the US were organised on the first ever Bioenergy Day,**

support, and facilitation of integrative multidisciplinary efforts in research, education/training, and public service and outreach in the area of bioenergy across the campus, state, region, country, and world.

UGA faculty who are members of BSRI represent the university's strengths in agriculture, forestry, environmental science, engineering, carbohydrate science, genetics and microbiology. The institute also has affiliate members from industry, government and other organizations.

Robert Scott, executive director of BSRI, and associate vice president for research at UGA, explained that BSRI's mission is a reflection of UGA's tripartite mission as a land grant university: research, instruction and outreach.

BSRI facilitates basic and applied research projects in bioenergy that recognize the entire bioenergy lifecycle and environmental impact – from biomass production and harvesting to transport, treatment, conversion, and recycling. It also facilitates education and training of the next generation of scientists and engineers that will form the 21st century workforce in the alternative energy field.

BSRI's outreach mission, said Scott, is to involve our public and private stakeholders in the development and dissemination of next-generation bioenergy technologies.

*“Education and outreach are critical components of the BSRI mission,” said Scott. “We believe it is important to provide unbiased information to the public about renewable energy science and technology and how this might impact their lives.”*

*“If we can provide students practical hands-on experience with the science concepts, we can help them develop the tools necessary to understand the tradeoffs between fossil fuel-based and renewable energy futures.”*



*(University of Georgia)*

One of UGA's most significant bioenergy projects, the BioEnergy Science Center, or BESC, provided a ready source of bioenergy education and outreach experience for UGA's Bioenergy Day.

### **Farming for Fuels**

BESC is one of three Bioenergy Research Centers established by U.S. Department of Energy's Office of Science in 2007 to accelerate research toward the development of cost-effective advanced biofuels. UGA is one of the 18 institutions that partner through BESC on multidisciplinary research (biological, chemical, physical and computational sciences, mathematics and engineering) focused on the fundamental understanding and elimination of biomass recalcitrance. One of BESC's goals is to educate and inform students about the basics of energy production and utilization.

Jan Westpheling, UGA professor of genetics, and the leader of the BESC outreach team, was excited about the opportunity to bring BESC's bioenergy outreach program to Athens. In partnership with the Creative Discovery Museum in Chattanooga, Tenn., BESC staff at UGA and Oak Ridge National Laboratory had developed a highly successful set of hands-on exhibits and lesson plans about producing renewable

**“ We believe it is important to provide unbiased information to the public about renewable energy science and technology and how this might impact their lives. ”**

energy from biological sources, called Farming for Fuels. The activities teach basic concepts such as the carbon cycle; how woody biomass, such as trees and grasses, can produce biofuels; and the technical and economic obstacles to a bio-based fuel economy. The BESC outreach program has expanded nationally to reach more than 60,000 students, teachers and parents by partnering with museums and centers in Tennessee, Georgia, Texas, Michigan, Illinois, Florida, New York and Arizona, but the Bioenergy Day @ UGA last October was the program's first visit to Athens.

*“The nine Farming for Fuels work stations allow students to understand fundamentals of the complex nature of plant cell walls, the issues affecting the use of food versus nonfood crops to produce biofuels such as ethanol, and the mechanical differences between cars run by hydrogen, solar and wind power,” explained Westpheling.*



(Leslie Bobby)

For example, one activity involves testing the sugar content of different liquids and learning how yeast ferments sugar into ethanol for biofuels. In another activity, students use a microscope to see the differences between plant cells with their thick cell walls of cellulose and animal cells with thin cell membranes. Students visiting the different exhibits can plant seeds, grind corn, soybeans and grass; and make molecules of water, ethanol and other fuels.

Once the students who visit the Farming for Fuels exhibits are back in their classrooms, lesson plans from the Creative Discovery Museum help teachers teach more about biofuels.

### **Willing partners make it happen**

University of Georgia partners were eager to join in the Bioenergy Day @UGA effort.

The State Botanical Garden was a natural partner. As a Public Service and Outreach unit of the University of Georgia, the Botanical Garden provides the public of all ages and UGA faculty

and students opportunities for recreation, events, research and learning through its natural areas, display gardens and building spaces.

The planning committee considered locations on the central UGA campus, but kept coming back to the Botanical Garden as a potential location for the event. With its beautiful natural setting and excellent facilities – including the Callaway Building’s indoor conference and meeting space – needed to protect exhibits in the event of rain, and adjacent outdoor space – needed for parking the bus-sized mobile gasifier, it was a perfect fit. Moreover, the Botanical Garden staff were enthusiastic and supportive of the educational mission of the event. In addition to a library, laboratories, and offices, the building contains an auditorium, reception area, and conference and meeting facilities.

The UGA Office of Sustainability, which leads the university’s programs advancing campus sustainability efforts, with its mission of providing leadership on environmental issues, was another natural partner for BSRI.

The staff from the Creative Discovery Museum staff, who made the 175-mile drive from Chattanooga to Athens the night before, were undaunted by the prospect of 200 middle-schoolers descending on their exhibits. Staff for the mobile gasifier also were well prepared for the students. Their efforts were assisted by the UGA Office of Service Learning, which connected the event organizers with the middle school, and recruited and organized over 50 UGA faculty and students to be on hand to guide the 7th graders through the hands-on displays. The Service learning staff also provided the liaison with the students’ teachers to assure everyone knew what to expect.

On October 8, the Hilsman Middle School students arrived on school buses starting at 9:30 a.m. For two hours, the group of high energy students in the first wave followed their curiosity from exhibit to exhibit, and after a brief pause, the second wave flooded the Botanical Garden’s Callaway Building. And by 1:30, the students had returned to their classrooms.

*“The students were excited about the exhibits and I am sure some of them walked away with a lot of new interest in science,”* said Dan Geller, UGA College of Engineering, and chair of the BSRI Outreach committee. *“We couldn’t have done it without all of our willing partners, but we’re already planning on doing it again in 2014.”*

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# WASTE-TO-ENERGY: CONSERVING PLANT GENETIC RESOURCES, IMPROVING LIVELIHOODS

Nature Palace Botanic Garden (NPBG) in Uganda is a unique community botanic garden whose conservation priorities are largely informed by identified community needs.

## Introduction

**N**NPBG in central Uganda, East Africa was started in 2001 with a special focus on medicinal plants that are crucial for the treatment of common ailments in the local community. Such medicinal plants are now becoming less and less accessible due to a number of factors which include deforestation, agricultural expansion, urbanization etc. The botanic garden is administered and financed by Nature Palace Foundation. In 2005, NPBG was registered as a participant in the world-wide implementation of the International Agenda for Botanic Gardens in Conservation.

## Uganda's cooking energy paradox

Uganda as a country is losing its natural forest estate at a rate of 2.3% per annum with overall forest cover dropping from 24% to 18% between 1990 and 2005 (Forestry sector support, 2009). According to the National Environment Management Authority, Uganda already had a fuel wood deficit of 2.7 million cubic metres in 1986. The increase in fuel wood consumption for industrial use is also on the increase. The main contributing factors to such a fuel wood dependence situation include: limited

access to electricity, high electricity tariffs and prices of alternative fuels (MEMD, 2006).

While Uganda's natural forests continue to be over-exploited and depleted, rural and urban populations have been increasing. The unsustainable rate at which forests and trees have continued to be exploited, coupled with the increasing population, ineffectiveness of forest resources management programs, and unabated poverty in rural areas makes the attainment of sustainable development and environmental sustainability challenging. High dependence on fuel wood and charcoal for cooking within the context of depleted natural forests and trees further adds to the problem.

## The genesis of the Waste-to-Energy Program by NPBG

Natural forests act as living gene banks and in the case of Uganda are believed to contain a good number of plant species which are not yet documented and therefore not recognized in the scientific world. With every forest cleared a wealth of plant genetic resources is therefore bound to be lost.

With only 5% of the rural population having access to electricity, more than



*A 3-stone cookstove – wasteful and a health hazard*

90% of the country's total energy needs come from biomass sources. Of this, wood accounts for 80%, charcoal 10% and crop residues at nearly 4%. Wood in the form of firewood and charcoal are the main sources of cooking energy available for the majority of Ugandans, providing about 93% of the country's total cooking energy needs. The household consumption of firewood and wood for charcoal was estimated at 22.2 million tons in 2006 (MEMD, 2007), with small-scale industries consuming another 5.5 million tons creating a total annual biomass demand of 27.7 million tons. Annual biomass consumption per



*Making briquettes manually*

capita is estimated, for rural and urban areas respectively, at 680 kg and 240 kg of firewood and 4 kg and 120 kg of charcoal. Fuel wood therefore is a key driver of deforestation. People have to cook their food to survive; therefore no kind of sensitization can stop them from clearing forests for fuel unless an alternative is provided. This is the reason why NPBG came up with the Waste-to-Energy program to provide an alternative fuel. The program is based on the notion that our impact in regard to plant resources conservation is more limited if we don't do something about the alarming rates of deforestation.

**How the Waste-to-Energy program is contributing to plant genetic resources and controlling deforestation**

NPBG's Waste-to-Energy program focuses on the production of fuel briquettes for cooking. Briquettes provide a suitable alternative because they are perfect substitutes for charcoal that provide the main form of cooking energy among urban and peri-urban dwellers. The fuel briquettes are cheaper than charcoal providing a saving, while they can cook for a longer time than charcoal. This fits well in the social-cultural context in central Uganda where food (especially banana) is simmered for a long time. Fuel briquettes have a higher heating value than wood or charcoal, are smokeless when burning and give off an intense and steady heat.

Relating it to greenhouse gas emission reduction, since briquettes are made of waste material, the green house gas emissions savings can be thought of in terms of the number of trees left standing as a result of replacing firewood and charcoal.



*A traditional wood stove*

*It is estimated that each ton of charcoal requires the felling of 88 medium sized trees. Using this figure the total amount of deforestation avoided by the Waste-to-Energy program by NPBG is equivalent to 8,030 trees annually and there are plans to triple this figure by the end of 2014.*

**The multi-pronged benefits of a Waste-to-Energy project**

Recycling of solid waste into fuel briquettes utilizes an appropriate technology that presents a number of environmental, economical and social benefits. Generally, it addresses deforestation, health related problems, unemployment etc. Specific examples of the potential of waste recycling technology include:

- Reduces rate of deforestation – each ton estimated to save about 88 medium sized trees;
- Reduces greenhouse gas emissions by saving trees that would otherwise be cut to provide firewood and charcoal;
- Controls respiratory problems, especially among women and children that are associated with excess inhaling of smoke;
- Enhancement of hygiene and sanitation conditions in communities and households;
- Reduces work-load of women and other gender-based vulnerabilities;
- Good candidate for Carbon Trade as a sustainable financing mechanism. The potential for carbon trade presented by this intervention is a strong pointer to long-term financing hence to sustainability and greater opportunities for poverty reduction.



*Making clean cookstoves*



*Exhibition: Energy from waste*



Burning briquettes



Drying briquettes

### The health impacts of smoke from wood stoves

*Exposure to smoke from traditional cookstoves and open fires – the primary means of cooking and heating for nearly three billion people in the developing world – causes almost two million premature deaths annually, with women and young children the most affected. In sub-Saharan Africa and Asia, the lack of access to clean cookstoves and fuel for cooking is especially acute, with a third of the urban population and the vast majority of the rural poor using firewood and charcoal to cook their daily meals over open fires or inefficient stoves. Smoke from cooking contributes to a range of chronic illnesses and acute health impacts such as pneumonia, lung cancer, chronic obstructive pulmonary disease, cataracts and low birth weight. In fact, the World Health Organization states that harmful cookstove smoke is the 5th worst overall health risk factor in developing countries (Global Alliance for Clean Cookstoves). The carbonization process used in making the briquettes reduces the amount of harmful emissions compared to burning raw biomass.*

### How briquettes are made

Fuel briquettes are processed biomass fuels that are burned as an alternative to wood or charcoal for cooking and heating. They are made by compacting loose biomass residues into solid blocks that can replace fossil fuels. The process of making briquettes involves

carbonizing the biomass material, mixing with a binder e.g. cassava starch, compacting and finally drying the compacted material.

### The waste situation in the Country

Uganda's urban and peri-urban centres generate a lot of bio-wastes resulting from the eating and food preparation habits of the population. Over 70% of the wastes are biodegradable. At the moment such wastes are a major challenge because of the characteristic absence of an effective system of collection, poorly managed or uncontrolled dumping sites and a big percentage of un-collected garbage. In Kampala, for example, according to the National Environment Management Authority, only an estimated 50 - 70% of the generated solid waste is collected and well managed. Such conditions largely contribute to the pollution of the environment and the proliferation of diseases and in many cases there are disputes from communities near the dumping sites. The Waste-to-Energy program therefore is turning a problem into an opportunity.

### The role of Nature Palace Botanic Garden

The Waste-to-Energy project at NPBG is implemented at various levels:

- NPBG has developed a briquette production unit which, as well as producing briquettes for various objectives including demonstration/ training, also serves as a training unit.
- The briquettes are used at the garden for cooking needs and the excess are sold to the public.

- However, production and selling briquettes is not the core business of NPBG. The main focus is to promote and train other groups, individuals or companies that can take this on as a business venture.

### Challenges

- Technological limitations: The technologies used are still rudimentary. While advanced technologies that can produce better quantities and quality exist, they require a big investment;
- Limited financing for technological and quality improvement;
- Opportunities in the voluntary carbon market remain complex and un-tapped.

### Recommendations

- Partnerships for carbon trade: We need to develop partnerships with institutions that are more conversant with carbon trade issues;
- Partnerships for technological development which should lead to quality and quantity improvement hence impact;
- There is need for increased investment in innovation and research in Appropriate Technology such that simple adoptable technologies can be further developed and up-scaled.

### References

- Forestry sector support. 2009. Department of the Ministry of Water and Environment, Government of Uganda.
- Ministry of Energy and Mineral Development. 2006. Government of Uganda.
- Uganda Renewable Energy Policy. 2007. Ministry of Energy and Mineral Development, Government of Uganda.

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# ENALGAE PILOT AT THE CAMBRIDGE UNIVERSITY BOTANIC GARDEN

## A CASE STUDY OF BIO-ENGINEERING WORK

This pilot facility has grown out of a long-standing collaboration between InCrops at the University of East Anglia and the Department of Plant Sciences University of Cambridge. InCrops is a partner in the Energetic Algae Project, known as EnAlgae, which seeks to establish what role algae can play in the development of a low carbon economy. The pilot plant at the Cambridge University Botanic Garden is one of a network of EnAlgae facilities that is co-funded by the INTERREG NW Europe strategic initiative.

Cambridge Water is also supporting the project, as the company is interested in the bioremediation aspects of the work. Most drinking water in the region comes from boreholes, which are becoming increasingly contaminated with nitrate leaching through the soil. The process to remove nitrate from groundwater is highly effective, but the drawback is the creation of a by-product of nitrate-rich brine. The EnAlgae pilot is being used to test if the brine might be a suitable source of nutrients for microalgae. This contributes to the wider interest in finding solutions to turn waste into a re-useable resource with value.

The facility showcases a six metre long photobioreactor with patented low energy design by Steve Skill, another EnAlgae collaborator. The reactor has a capacity of 300L, and will be used to test the growth of a variety of commercially promising algal strains. Disposable bag reactors are used to run smaller experiments, and generate inoculum for the bioreactor.

At present, several different species of marine microalgae are being tested for their ability to grow in the presence of

In one of the overwintering polytunnels at the Botanic Garden in Cambridge, there is a new and rather unusual addition nestled between the papyrus and the banana trees. The garden is acting as a host for a pilot plant, testing how feasible it is to culture microalgae in our geoclimatic conditions.



*Brenda Parker from EnAlgae explaining to visitors which algae are grown in the disposable bag reactors*

**“ The Botanic Garden is delighted to host this exciting new facility. This project is a great example of how different scientists can work together to explore the full potential of green organisms to tackle global concerns, an ethos that underlies much of our work at the Garden. ”**

*Beverley Glover,  
Director of the Botanic Garden*

the brine wash. All of the data gathered from the experiments is fed into a central database. This will enable other partners to use computer models to better predict the impact of location and climate conditions on microalgal growth. This is one of the many reasons that the interaction with the Botanic Garden has been advantageous. Horticultural teams recording temperature and sunlight can share this vital information with the EnAlgae researchers.

One of the interests of the EnAlgae project is to understand if microalgae can be a viable feedstock for bioenergy. Algal biomass can be used as a feedstock for anaerobic digestion, and lipid extracted from the microalgal cells can be converted into biodiesel. There are a number of challenges to making this economically feasible, as microalgal



*The polytunnel in which the algal growth facility is located; the experimental set-up is being discussed with staff at the Botanic Garden*

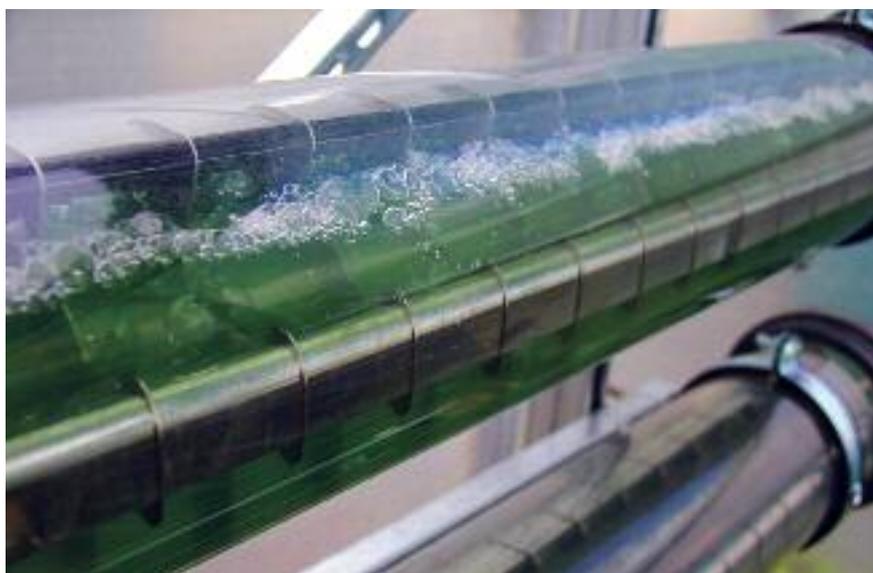
cultures are effectively very dilute, typically only 1-5 grams per litre of culture media. By exploring some of the vast biodiversity of microalgal species, there may be potential to improve the viability of this. However, biofuels are not the only interesting aspect of microalgae. Lipids can be utilised for their Omega 3 fatty acid content in a nutritional context, protein can be used to supplement animal feed, and antioxidants have applications in cosmetics and nutraceuticals.

Outreach events are a key component of the project, and the EnAlgae team based at the Garden have organised tours, talks and workshops exploring the various applications for microalgae. This work supports the small, but growing algae industry in the UK. The EnAlgae team also work with the education department at the Botanic Garden to use the facilities for educational visits and as a learning resource for schools.

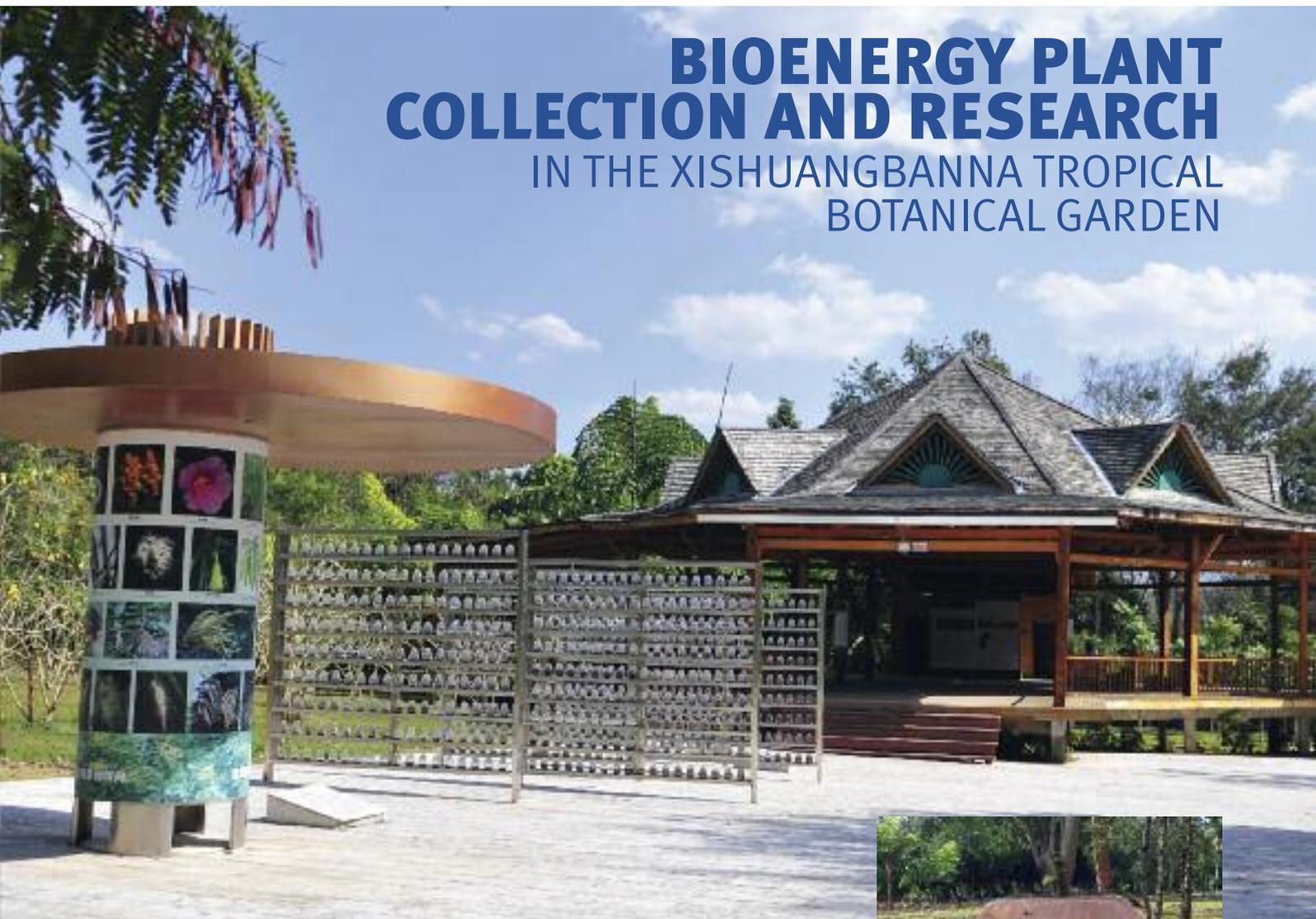
*For further information about Cambridge University Botanic Garden, please see [www.botanic.cam.ac.uk](http://www.botanic.cam.ac.uk); to learn more about the EnAlgae Project, please visit [www.enalgae.eu](http://www.enalgae.eu).*

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*The photobioreactor, patented design by Steve Skill*



# BIOENERGY PLANT COLLECTION AND RESEARCH IN THE XISHUANGBANNA TROPICAL BOTANICAL GARDEN



*The science exhibition area at XTBG*



*A wooden car is part of the Bioenergy Garden display*

## Introduction

Development of sustainable bioenergy can reduce our reliance on fossil fuels, improve environmental quality, and increase the income of farmers. The development of the bioenergy industry will very much depend on the use of feedstocks and their genetic resources for breeding. Meanwhile, to achieve low carbon development requires the promotion of low carbon lifestyles and the use of carbon-neutral energy. Botanical gardens could be ideal settings for promoting the ideas and developing new feedstock varieties and technology on these aspects.

## Bioenergy plant collection

China has around 31,000 species of vascular plants accounting for 10% of the world's total, of which about 4,000 species have potential for bioenergy development. Xishuangbanna Tropical Botanical Garden (XTBG) of the Chinese Academy of Sciences is the largest botanical garden in China with an area of 1,125 ha. It is located in the southern part of Yunnan province in southwest China, bordering Myanmar, Laos and Vietnam. Its collections include over 12,000 species of tropical and subtropical plants cultivated in its 38 living collections. Among which, about 695 species make up the bioenergy plant collection.

The Bioenergy Garden in XTBG covers an area of 13 acres. The garden comprises of three areas: the classified collections, the miscellaneous collections, and the popular science exhibition area. It has collections of

more than 5,400 energy plants of 350 species belonging to the 50 families. Based on the compounds of biomass in the plants, the Bioenergy Garden is divided into 5 functional collections, including oil, starch, hydrocarbon, fiber, and firewood plants. About 1,490 plants of 141 species belonging to Euphorbiaceae, Myristicaceae, Lauraceae, etc. are grown in the living collection of oil plants, about 1,410 plants of 57 species belonging to Fagaceae, Araceae, Dioscoreaceae, etc. in the living collection of starch plants, about 400 plants of 12 species of the Euphorbiaceae in the living collection of hydrocarbon plants, about 1,850 plants of 136 species belonging to Urticaceae, Malvaceae, Tiliaceae, etc. in the living collection of fiber plants, and about 250 plants of 4 species belonging to Caesalpiniaceae, Mimosaceae, etc. in the living collection of firewood plants. These bioenergy plants are widely used or have a great potential for biofuel development in tropical and subtropical areas. Examples of these bioenergy plants include: physic nut (*Jatropha curcas*), which is the most studied bioenergy plant in XTBG, and an oilseed plant used for producing biodiesel and bio-jet fuel; cassava (*Manihot esculenta*), a starch plant used for producing bio-ethanol; African milk bush (*Euphorbia tirucalli*), a hydrocarbon plant containing



Main entrance to the Bioenergy Garden

a poisonous latex that can be easily converted to the equivalent of gasoline; Miscanthus, the fast-growing perennial grasses with a great potential for production of cellulosic ethanol; and *Senna siamea*, a tree widely used by the natives of the minority nationality Dai as a firewood.



A biofuel plant – *Jatropha curcas* – in the Bioenergy Garden



Wall of hopes in the Bioenergy Garden (showing various seeds of bioenergy plants in heart-shaped glass bottles)

**Display and exhibition for education**

In the popular science exhibition area, visitors can view various displays about bioenergy, such as charts and posters in the bioenergy exhibition hall, sculptures, wall of hopes, wooden car, wooden pistons, and seaweed columns. Thus visitors can see the whole picture of the bioenergy industry, including feedstock



Wooden pistons in the Bioenergy Garden

“By visiting the energy garden, visitors can learn about the whole process, from growing the plant to using the biofuel and understand the connections with

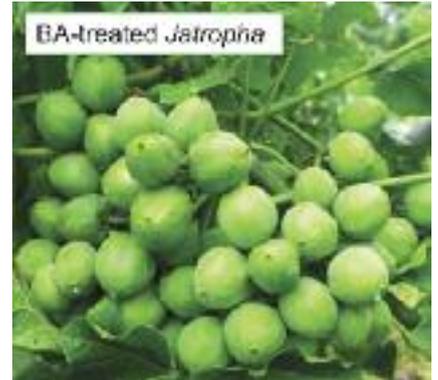
supply and logistics, biomass processing and conversion, biorefineries, distribution, bioenergy end use, sustainability, and environmental risks. By visiting this energy garden, visitors can learn about the process from growing bioenergy plants in the field to storing biofuels in fuel tanks, and to can understand the linkages between biological resources and the biofuel industry and connections with global climate change.

This Bioenergy Garden shows the relationship between bioenergy plants and the life of humans, and also provides a good platform for scientific research and exploitation of bioenergy plants. The exhibition of bioenergy plants and the dissemination of new biotechnologies for bioenergy is expected to have an impact on China's national bioenergy policy and legislation. We believe that tropical areas with abundant rainfall and sunlight are the best place for bioenergy development, and the perennial woody oil plants are the sustainable biofuel feedstock.

### Bioenergy plants research

To take full advantage of these collections of bioenergy plants and promote bioenergy development in China, XTBG has established several

research groups devoted to working on such aspects of bioenergy plants as germplasm collection and evaluation, functional genomics, conventional breeding (e.g. hybrid, mutation, polyploid), transgenic breeding, tissue culture propagation, large scale plantation, biofuels conversion, and environmental effects. As an example, we found that treatment with the plant growth regulator 6-benzyladenine (BA, a synthetic compound with cytokinin activity) significantly increased the seed yield of the biofuel plant *Jatropha curcas* by promoting female flower tendency and increasing the percentage of female flowers and the number of flowers per inflorescence, thus resulting in an increase in fruit number (Journal of Plant Growth Regulation 30 (2): 166-174, 2011).



Planting growth regulator 6-benzyladenine (BA) treatment significantly increased the seed yield of the biofuel plant *Jatropha curcas*

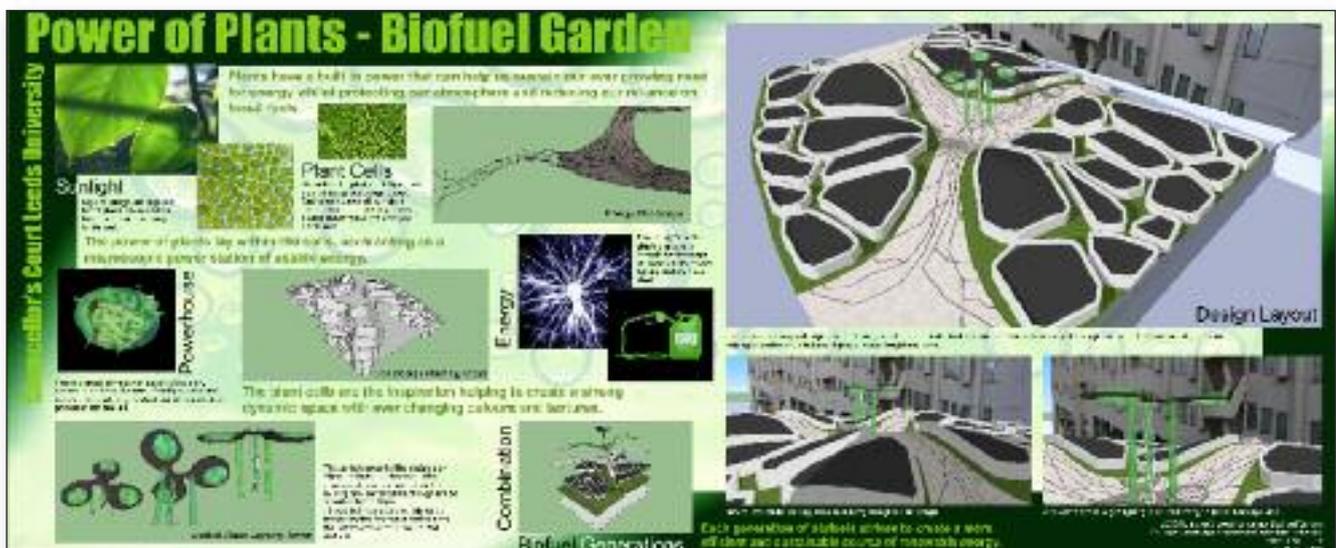
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Living collections of bioenergy plants in the Bioenergy Garden

# DESIGNING AN ENERGY GARDEN

Trudi Entwistle, a senior lecturer in Landscape Architecture at Leeds Metropolitan University, UK, in collaboration with Dr Jon Lovett and the School of Geography at Leeds University, challenged her students to design an interpretive Energy Garden as part of their course. The students, who were studying for BA (Hons) degrees in Landscape Architecture and Garden Design, were asked to design something that could potentially be used by botanical gardens to explain to the public about biomass energy using energy plants in an attractive and informative setting. Here we present their results and the thinking behind their innovative designs.



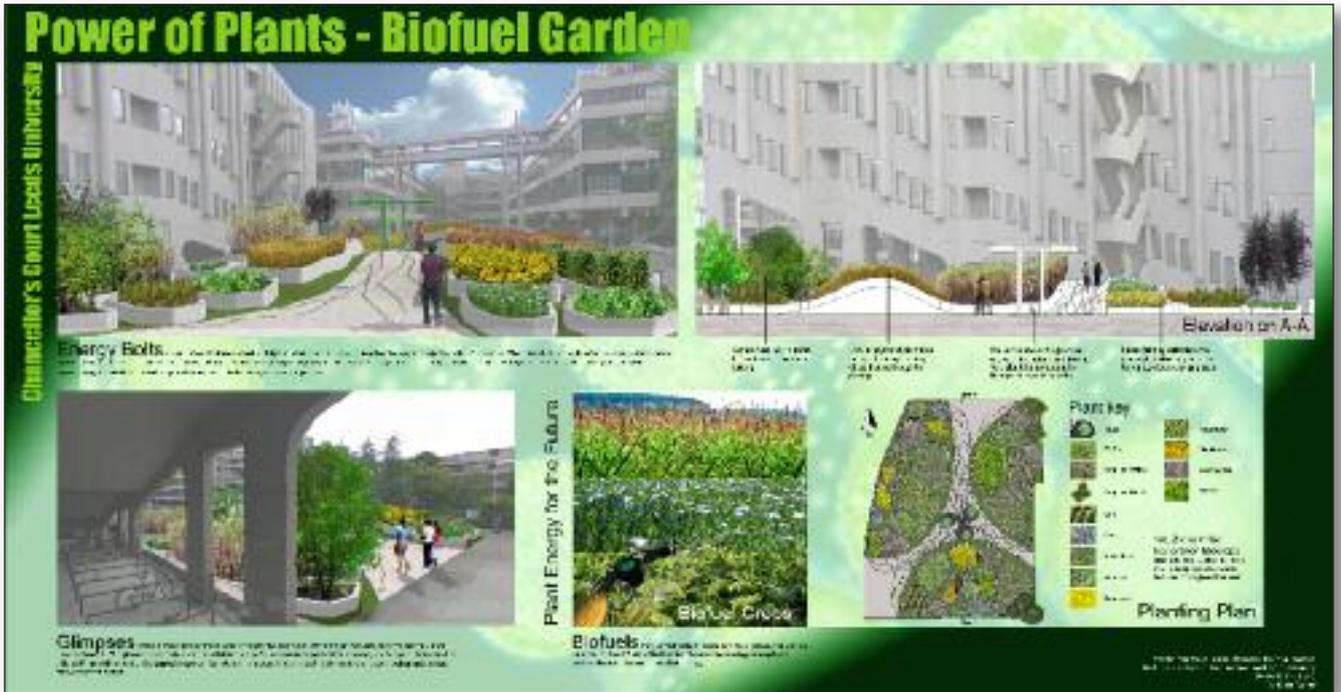
**Mike Tucker:**  
**Power of Plants – Biofuel garden**

The task of designing an energy garden was an interesting and challenging one, especially not knowing a great deal about the subject. After some desktop study, in which I just scratched the surface, I was surprised at the amount and variety of vegetation that can be used within the process of producing biofuel.

As I looked further my main focus became the cells within the plants which hold the key to the production of usable energy. These cells then formed the main concept of my design, using them as inspiration to create a contemporary modular layout that would showcase a variety of biofuel vegetation. Each planting area contains a different type of biofuel crop, creating a wider awareness of the variety of plants used.

*“Plants have a built-in power that can help us sustain our ever growing need for energy, whilst protecting our atmosphere and reducing reliance on fossil fuels”.*

The central element of the design is an algae producing light tower which allows waste carbon dioxide from the building services to bubble through and be absorbed by the algae. Energy bolts,



created from stainless steel and lighting dart along the paving leading the way through the cells of the bio-crops. 1st, 2nd and 3rd generation bio-crops populate the garden, creating ever changing colours and textures throughout the year.

*“Creating an energy garden design has been a real eye-opener with respect to the world wide need for local, clean, renewable energy sources that can benefit not only the masses but also small remote communities cut off from the mainstream of modern life.”*

**Planting:** Algae, barley, coppiced willow, coppiced hazel, flax, maize, miscanthus, potatoes, rapeseed, sugarbeet, sunflower, switchgrass and wheat.

### Chrissy Lee Overend

My concept for the energy garden was to try and make others aware of unusual ways of extracting fuel. I wanted to also remind us of the fight between new and old methods of creating energy.

The garden uses algae, bamboo and eucalyptus for producing biofuel.

The design demonstrates how energy sources can be extracted from unusual places, such as an aesthetically pleasing area, which at first sight may appear to

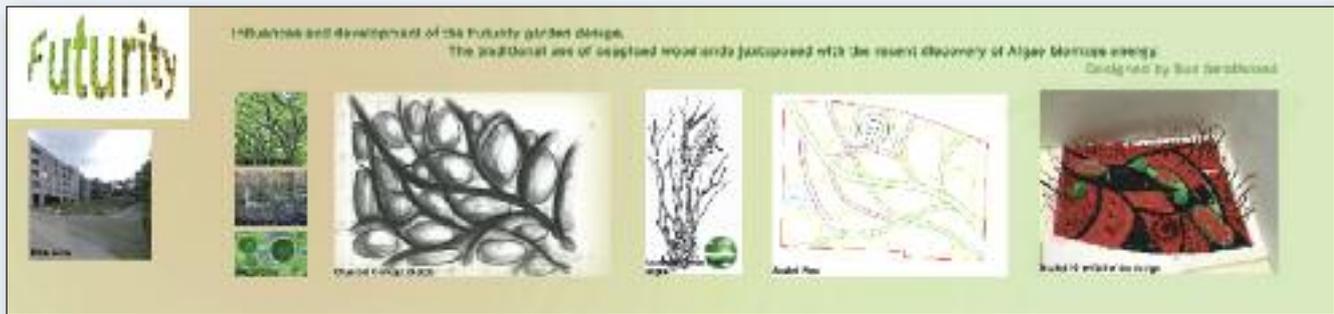
be no more than an attractive garden. As well as this, the garden and its plants have promise for the future, when even more revolutionary methods of energy extraction are refined.

The garden includes coal gambion cubes with algae tubes around them to show the fight between old and new.

**Planting:** *Eucalyptus gunnii* – selected for its suitability for the UK climate, its rapid early growth and the fact it retains foliage in the winter. Species of bamboo (*Phyllostachys aureosulcata*, *P. nigra* and *P. aurea*) were selected for variety of colour and ability to regenerate rapidly after harvesting.

*“I enjoyed having the chance to learn more about energy sources and how these are extracted. The challenge to put this knowledge in to a working design was very useful and I feel will help me in future designs.”*





**Sue Smallwood:  
Futurity**

*“Initially the concept of designing an energy garden on a small scale was a little daunting, however being pushed out of your comfort zone is always testing. The more I researched the subject, the more fascinating it became. The garden had to be representational rather than productive due to the size and the amount of fuel you could produce each year.”*

The design raises awareness of the diversity of fuels, which can be grown within our climate. I initially used charcoal, which is a by-product of fuel, to produce the concept for the design. This helped me to produce organic shapes, incorporating crop rotation and seasonal changes, producing an ever-changing design for the garden. Not only did I have to consider the fuel, but also the long-term effects of cropping and the ever-changing arrangement of space, scale and the aesthetical repercussions.



The garden aims to reflect the juxtaposition of old and new biofuels. The algae sculptural spheres light up, absorb carbon dioxide and represent the world’s future fuel and energy. The garden works on a six-year crop rotation for the coppiced woodland area.

*“My knowledge of biofuels, their uses and design has increased dramatically after this module making me even more aware of the consequences we face when making fuel choices.”*



**Jacqui Tucker:  
The Energy Garden**

*“After being assigned the task of coming up with a scheme for an energy garden, I wondered what direction I would take for the new design. Inspired by the knowledge that fossil fuels and natural resources are rapidly depleting, through over exhaustion and the fact that we are bleeding the earth dry, my research made me look deeper into renewable energy and how it could be used on large and small scale projects.*

*I came up with the idea of ‘Urban Farms’, where bio fuel crops were grown on roof structures, plazas and road side verges within the inner city, these crops would then be used to produce heat sources through composting and bio fuel through the waste products. This process became*



*a celebration of the power locked within plants and within its 'life cycle' of growth, harvest, and decay then finally being reborn into a renewable energy source."*

From our constant destruction of the planet and near exhaustion of fossil fuels, this urban farm is a place that harnesses the power of plants to produce heat, light and electricity. It is a place that brings with it life, hope, nurturing and inspiration as we move forward to the next generation and to the

future of biofuel energy. The Energy Garden is a celebration of the beauty, diversity and the potential source of new energy found within plants, representing a new beginning and a new future for our environment. The algae sculpture represents a new beginning and step towards the future. The design's inert centre symbolizes the past depletion of fossil fuels as a non-renewable source, the radiating planted pods contrast new vibrant growth that celebrated a renewable future.

**Materials:**

- Filterpave – a 39% permeable surface made from colorful mosaic of 100% post-consumer glass aggregate solidified with a 60% natural plant-based bonding polyurethane.
- Recycled concrete
- Rainwater harvesting using underground tanks
- Reed bed system to filter 'grey' water using *Phragmites australis*

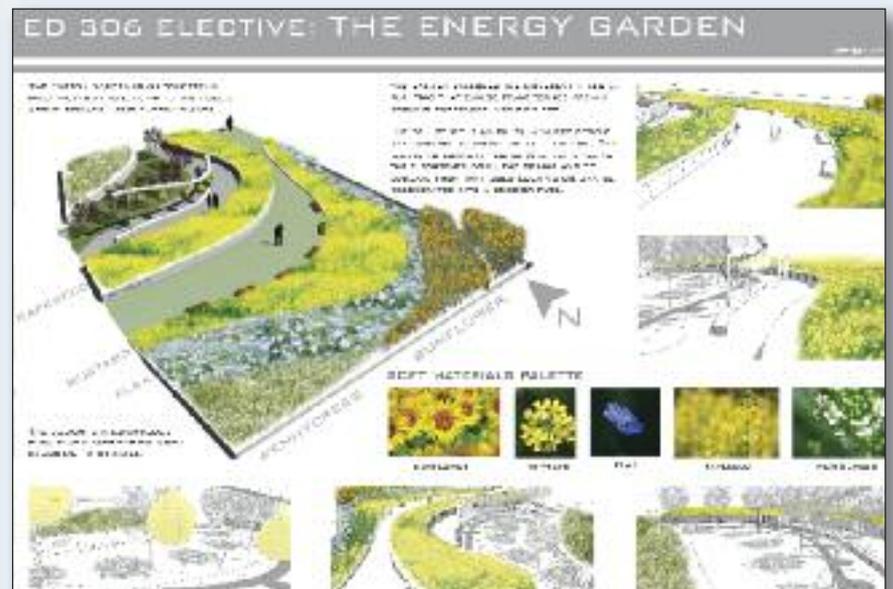
*All images are © Leeds Metropolitan University*

**Harpreet Rattan:  
The Energy Garden**

Bio-fuels have been accepted as a potential to resolve the challenges of the ever increasing demand on fossil fuels, petrol prices and climate change. The challenge to design an Energy Garden to fit in the calibre of Bio-fuels dumbfounded me.

*"Personally I found it quite difficult at first to conjure an idea. It's a new concept that no other Landscape Architect has covered and so the inspiration was dissipated. Instead of designers I looked into plants that make first and second generation fuels which included rapeseed, sunflower, mustard etc and that are grown in the U.K."*

The concept behind the Energy Garden is to inform individuals about biofuels. The garden design is to interpret the types of plants used to make biodiesel and also to make people understand that it's the oils unfit for human consumption that make the biodiesel.



The general layout of the garden is a contemporary design and the plants give height, texture and colour.

The garden design is a curvaceous flow that mimics oil when in contact with water. The garden includes a sculpture

which is an oil tank where people can dispose of their used cooking oil. The idea is to convert people from discarding oil down their drains and help them to learn that used cooking oil can be regenerated into a greener fuel.

# HASSAN BIOFUEL PARK – A CONCEPT FOR PROMOTION OF REPLENISHABLE GREEN ENERGY

The Hassan Biofuel Park near Bangalore in southern India is a centre for providing appropriate technology to build a rural energy base with community participation using local plant diversity.

## Introduction

The Biofuel Park uses indigenous flora integrated into sustainable agricultural production, to help meet most of the farmer's energy demand. The Biofuel Park concept was initiated to create a strategy of developing the feed stock supply chain through participation of the farming community that made use of marginal lands, and which did not affect agricultural production. The strategy investigated how non edible oil seed crops, such as *Pongamia*, *Mahua*, *Simarouba*, *Neem*, *Calophyllum* and *Mesua*, could produce energy feed stocks throughout the year to meet raw material needs. The Park is a novel concept developed by the University of Agricultural Sciences Bangalore and the Government of Karnataka. The aim is to use non-edible oils derived from a diverse mix of species beneficial to agriculture, primarily on land not being used directly for agriculture. This provides an additional activity for farmers to give added value at village level, generating rural employment and building energy security for the villages.

## The biofuel programme

The program was launched in 2007, following a six year development period, and covers an area of about 6,900 sq km with annual rainfall ranging from 7,000

mm along the Western Ghats, declining eastwards to about 450 mm. Given the diversity of crops and soil types, and with land holdings of individual farmers varying from 1 ha to 3 ha accounting for more than 80 % of land, it was a challenging task.

The major objectives of the programme were to develop self reliance in basic energy needs using local resources and



Fuel wood trees in the Hassan Biofuel Park



Village level meeting at the Biofuel Park



*Nursery of quality planting materials*



*Farmers carrying saplings for planting*

adopting appropriate technology, while generating employment and ensuring good agriculture production. This would be achieved by growing multipurpose trees in a decentralized manner providing benefits including oil seeds throughout the year and building a strong resource base in the villages.

Park activities started with the selection of better clones of tree oil seed crops for mass multiplication and planting in villages. Initial ground work was carried out on suitability of species, identifying high yielders in terms of oil content and seed yield, and developing vegetative propagation techniques through grafts, thereby advancing flowering and fruiting. The approach involved decentralised collection and processing of the seeds locally to minimise transport costs. Appropriate tools were developed for

use in rural areas for value addition; and by products were used locally as manure for food crops, oil cake as animal feed and as substrate for bio-gas production.

At the end of the value chain, the oil obtained from these oilseed trees was used to safely blend up to 20% with Petro diesel in agricultural machines such as tractors and irrigation pumps. The oil is also used in generators to produce electricity, and in the future there is the potential to meet primary power needs for lighting houses, pumping water for drinking; and also to electrify schools and primary health care centres.

### **Trees as a source of energy security**

Trees are a source of multiple resources in rural areas, meeting demands for food, fodder, timber, medicine, fuel, shelter for people and animals, manure, maintenance of soil health and water percolation. The extensive use of trees in agro ecosystems and their multipurpose nature has resulted in large scale planting both in urban landscapes and in rural ecosystems. A study of the trees across the different agro ecological regions of Karnataka, India revealed more than 350 promising species of oil yielding plants with potential for alternatives to petroleum and diesel fuels.

Further analysis of the species also showed that more than 15 species were distributed across habitats from the coast to hills in both wet and dry regions, with as many as eight species enjoying a wide ecological and climatic range with good yield of oil from their seeds. Traditionally these oils were already being used for lighting lamps, medicine and for other household needs.

The plant species adapted to different climatic and edaphic situations yielding oil seeds in different parts of the year making the system work all through the year are listed in Table 1.

These trees are grown along borders, bunds, back yards, avenues, ravines and also in community lands and degraded lands. They serve as good soil binders, wind breaks, aid water percolation, provide plant litter biomass to improve soil fertility, minor timber, fuel and also provide fruits which have a seed oil content in the range of 20-70%. In contrast to edible oils derived from agriculture these trees do not compete with food production, but rather, sustain it.

### **Achievements of the Biofuel Park:**

- **2110 villages** covered for data inventory.
- **1,524,949** seedlings of five bio-fuel crop species produced (Honge, Hippe, Neem, Jatropha and Simarouba)
- **Planting on 19,008 acres** (equivalent on bunds, margins, waste lands, ravines, community lands etc.)



*Simarouba and Maize intercropped*

Name	Seed yield-kg/ per tree	Oil (%)	Harvest season
<i>Aphanamixis polystachya</i>	20-25	40-44	December - May
<i>Azadirachta indica</i>	10-25	25-30	June- July
<i>Calophyllum inophyllum</i>	30-40	48 -65	April-May October-December
<i>Jatropha curcas</i>	0.5-1.0	30-45	August-October
<i>Madhuca indica</i>	20-40	35-45	July - August
<i>Mesua ferrea</i>	20-40	50-60	August-October
<i>Pongamia pinnata</i>	20-40	28-38	January - March
<i>Simarouba glauca</i>	10-25	40-55	February- April

Table 1: Tree species yielding non edible oil

- **1,227** training programs held in villages of Hassan District.
- **261** on campus training programs held at the Biofuel park
- **2,012** Awareness programs held in villages of Hassan district.
- About **97,733 farmers** and interested people participated in the program with around 50% being women.
- Complete biofuel village with every household planting biofuel species – **70 villages**.
- **Market linkages** - feedstock with assured price and purchase
- **466** Oil seeds growers & collectors associations are formed.
- Additional production of **10,000 tons** of feed stock by 2016 in the district amounting to **Rs. 150 million**



#### References for further reading:

- Anonymous 1969. Wealth of India: raw materials. Publication and Information Directorate, Council of Scientific and Industrial Research, New Delhi, pp 206–211.
- Naik, M., Meher, L.C., Naik S.N., Dasa L.M. 2008. Production of biodiesel from high free fatty acid Karanj (*Pongamia pinnata*) oil. Biomass Bioenergy **32**:354–357.
- Pavithra, H.R., Chandrashekar Sagar, B.K., Prasanna, K.T., Shivanna, M.B., Balakrishna, G. 2013. Localisation of storage reserves in developing seeds of *Pongamia pinnata* (L.) Pierre, a potential agroforestry tree. J. Am. Oil Chem. Soc. **90**, 1927–1935.
- Pavithra, H.R., Balakrishna, G., Rajesh, K.K., Prasanna, K.T., Shivanna, M.B. 2012. Oil, fatty acid profile and karanjin content in developing *Pongamia pinnata* (L.) Pierre seeds. J. Am. Oil Chem. Soc.



Above: Agroforestry – millet and biofuel trees  
Top: A hand expeller

**“ The Biofuel Park aims to incorporate biofuel species into the local agricultural system and use them to develop rural energy**

**Biofuel Park Mission:**

To motivate farmers, women self-help groups and entrepreneurs, to provide an interactive coupling between technology, economy, environment and society for speedy development of the biofuel sector.

**Mission Objectives**

- To promote holistic growth of the biofuel sector through area- based regionally differentiated strategies;
- To increase the coverage of areas under biofuel plants in farmers' marginal lands, degraded forest and non-forest areas; with appropriate elite clones to enhance yields;
- To promote marketing of feed stock (seeds) locally;
- To establish convergence and synergy among stake-holders for development of biofuels, production, marketing, value addition and accrual of local benefits;
- To promote, develop and disseminate technologies for value addition and production of intermediary products;
- To generate employment opportunities for skilled and unskilled persons.

**Strategy**

To achieve the above objectives, the Mission would adopt the following strategies:

- Decentralised approach for production and marketing to assure appropriate returns to growers;
- Promote cooperatives and self-help groups to ensure adequate returns to farmers;
- Promotion of research and development on production technologies;
- Enhanced feedstock production;

- Facilitation of capacity-building and human resource development;
- Setting up village clusters and federations and networking to benefit members of the clusters.

**Key Elements of the Biofuel Park Mission**

- Research and development for biofuel species development;
- Identification of new candidates for biofuel production;
- Establishment of nurseries to raise quality biofuel seedlings;
- Raising high yielding biofuel species among the farming communities in marginal lands, borders and bunds and waste lands;
- Awareness building among farmers;
- Training farmers on biofuel value chain in villages;
- Building a market network of farmers and industries;
- Develop farmers association on the lines of the milk production system available in the country;
- Management of existing and new biofuel plantations;
- semi processing units at villages;
- Use of by products locally viz. de-oiled cake, production of biogas at home / community scale;
- Capacity building at village level.



A 2hp expeller

89, 2237–2244.

→ Pavithra, H.R., Shivanna, M.B., Chandrika, K., Prasanna, K.T., Balakrishna, G. 2010. Seed protein profiling of *Pongamia pinnata* (L.) Pierre for investigating inter and intra-specific population genetic diversity. *Int. J. Sci. Nat.* **1**, 246–252.

→ Prakash, D. and Misra, P.S. 1988. Protein content and amino acid profile of some wild leguminous seeds. *Plant Foods Hum. Nutr.* **38**, 61–65.

→ Shivanna, M.B. and Rajakumar, N. 2010. Ethno-medico-botanical knowledge of rural folk in Bhadravathi taluk of Shimoga district, Karnataka. *Indian J Tradit Knowl* **9**(1):158–162.

**Balakrishna Gowda**  
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**Forestry and Environmental**  
**Sciences, University of**  
**Agricultural Sciences,**



World biodiesel day celebration with the ICRAF/IFAD team

# RESOURCES

## Book Review

### Why People Need Plants

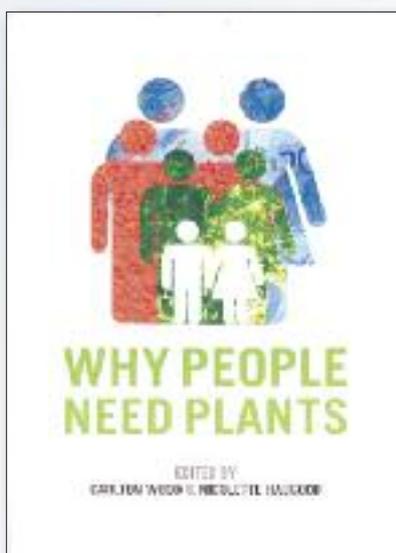
Carlton Wood and Nicolette Habgood (Eds.)

This book highlights the importance of plants and the ways in which people have adapted and impacted upon them, throughout history. Within its 15 chapters, it provides an overview of the variety of ways in which plants are invaluable to human survival.

Part one discusses the variety of ways we use plants, from food to forensics. Within this section chapter 4 is dedicated to the discussion of biofuels. Whilst accepting the historical significance of using biomass as energy, this chapter covers the modern day relevance of biofuels. This includes an overview of the types currently in use, for example, wood, grasses, biodiesel and bioethanol. The chapter explains how they are produced, along with considering biofuels and climate change and how these sources of energy can and have aided commitment to the Kyoto Protocol. The chapter closes with a discussion of the issues and controversies surrounding biofuels, which works to balance the ideas raised in the preceding pages. This includes the fact that the production costs of biofuels currently stand at double that of fossil fuels, biofuel crops, such as soyabean, have been blamed for a loss of biodiversity and some even argue that the production of certain biofuels makes them responsible for the release of more greenhouse gases than fossil fuels.

Part two covers plants' association with human health and discusses nutrition and medicine, along with plants that are used recreationally such as coffee, tea, cocoa and even cannabis.

Part three focuses on modern biological techniques, including micropropagation and genetic modification. As well as an



explanation of the methods used, the potential benefits and successes of these techniques are discussed, for example the production of insect resistant corn. However, the natural alternatives and their possible benefits are also highlighted.

Part four, concludes the book by considering 'plants and the planet'. The chapter includes an overview of the impacts humans have had on the planet and raises the need for conservation whilst discussing the various types. The chapter ends with a look the future which again highlights the importance of plants and swift human intervention in areas like food production and biodiversity loss.

This book offers the reader a glance at the many ways humans rely on and utilise plants from both a social and scientific perspective.

Published by Royal Botanic Gardens, Kew, Richmond, Surrey, UK. In association with The Open University, Milton Keynes, UK  
ISBN: 978-1-84246-425-0

### Beneficial Biofuels – The Food, Energy, and Environment Trilemma

David Tilman et al

Biofuels are often criticised for their potential to damage food production and the environment. This paper gives a brief and accessible overview of five potential solutions to some of the problems associated with these issues. For example: the possibility of using municipal waste rather specially grown crops or growing biofuel crops on disused land as to not to impact on food production and offer habitats to other species.

Science (2009) Vol: 325 pp:270 -271  
<http://www.sciencemag.org/content/325/5938/270>

### Bioenergy from plants and the sustainable yield challenge

Angela Karp and Ian Shield

A common criticism of the move towards biofuels is the argument that arable land, vital for food production should not be handed over for growth of biofuel crops, therefore the development of crops which grow efficiently and produce a large amount of usable biomass is essential.

This paper takes a scientific look at key bioenergy crops, including those grown for grain or seed, like wheat, grasses and fast growing trees like poplar, from the point of view of their usefulness as efficient sources of biofuel. This is followed by a discussion of the potential for improving their efficiency, for example, which plant processes to target, e.g. photosynthesis and how to optimise these process i.e. through traditional breeding or genetic techniques.

New Phytologist (2008) Vol: 179 pp. 15-32  
[www.newphytologist.org](http://www.newphytologist.org)

## Websites

### Bioenergy science centre



The Bioenergy Science Centre (BESC) conducts research with the aim of achieving easier access to the energy stored within biomass. This focuses on designing plant cell walls which are easy to break down and the development of microbes which can turn plants into biofuels.

Their website provides information, resources and tools to inform the public about the centre's research and bioenergy in general. The resources section includes various media which explain the role and research of the centre, along with the science behind it, for a range of scientifically literate audiences. This includes publications from BESC describing their current research. In addition there are factsheets and a page entitled 'biofacts' which summaries and explains BESC's work in more accessible language. There are also videos and audio recordings, which highlight the importance of their research and introduce some of the researchers.

For those looking for resources and ideas about how to teach young people about biofuels the Education section of the website includes information and resources aimed at children. These include lesson plans developed by BESC and the Creative Discovery Museum, Chattanooga, as well as links to engaging websites which aim to teach children about bioenergy and its importance.

<http://bioenergycenter.org/besc/education.cfm>

### Biofuel Park



The University of Agricultural Sciences, Bangalore's centre for excellence, Biofuel Park, aims to develop technology, interest and motivation to allow rural India to produce biofuels in a way which is supplementary to other agriculture. Its objectives involve the development of technology, strategies and community involvement to allow rural India to become energy independent whilst remaining rich in agrobiodiversity.

Their website includes details of the programme, their current research and activities, as well as providing a source of information for those wishing to gain insight into biofuels in general. The site includes a description of the various plants which are suitable for producing biofuels, including their physical characteristics and growth patterns. There are also brief and accessible summaries of the various methods which can be used to produce bioethanol and biodiesel.

<http://biofuelpark.org/>

### Guardian

In the Biofuels section of the Guardian's website you can find all of the paper's coverage of news related to this subject, including blogs and other media. From the most recent articles to those dating back to 2011, this resource offers an easily accessible look at development of this technology.

<http://www.theguardian.com/environment/biofuels>

### The Bioenergy site



Although biofuels offer great potential it is important to remember the possible dangers and weaknesses involved with this relatively new technology. In 2008 the FAO produced its report on 'The State of Food and Agriculture', in which there was a chapter devoted to the analysis of the environmental implications of the growth of biofuel crops.

This webpage offers an overview of the major themes of this section of the report, including the potential for biofuels to cause the release of large amounts of green house gases and the growth of biofuels degrading arable land. Additionally, there is a link to the relevant section of the FAO's report for those who wish to research these ideas in greater detail.

<http://www.thebioenergysite.com/articles/175/environmental-impacts-of-biofuels>



# Please **JOIN** Botanic Gardens Conservation International (BGCI) and help us to **save plants** from **extinction**

Established in 1987,  
BGCI links more than  
500 botanic gardens and  
conservation organizations  
in 115 countries,  
working together to save  
Plants for the Planet.

## BGCI's INSTITUTION members receive numerous benefits:

- Opportunities for involvement in joint conservation and education projects
- Tools and opportunities to influence global conservation policy and action
- Botanic Garden Management Resource Pack (upon joining)\*
- Our twice yearly e-publications:
  - *BGjournal* – an international journal for botanic gardens
  - *Roots* - Environmental Education Review
- A wide range of publications and special reports
- Invitations to BGCI congresses and discounts on registration fees
- BGCI technical support and advisory services

Institution Membership		£ Stg	€ Euros	US \$
A	BGCI Patron Institution	5500	7500	8500
B	Institution member (budget more than US\$2,250,000)	1000	1200	1500
C	Institution member (budget US\$ 1,500,000 - 2,250,000)	550	700	900
D	Institution member (budget US\$ 750,000 - 1,500,000)	400	500	650
E	Institution member (budget US\$ 100,000 - 750,000)	220	280	350
F	Institution member (budget below US\$100,000)*	100	120	150

**INDIVIDUAL members and donors** support BGCI's global network for plant conservation, and are connected to it through our publications and events.

## BGCI's INDIVIDUAL members receive

- Regular e-publications (these publications are sent as a pdf file via email):
  - *BGjournal* - an international journal for botanic gardens (2 per year)
  - *Roots* - Environmental Education Review (2 per year)
- Invitations to BGCI congresses and discounts on registration fees

Individual Membership		£ Stg	€ Euros	US \$
J	Conservation donor ( <i>BGjournal</i> and <i>Roots</i> publications & special reports)	275	375	400
K	Associate member ( <i>Roots</i> and <i>BGjournal</i> )	80	100	125
M	Friend-available through online subscription only ( <a href="http://www.bgci.org">www.bgci.org</a> )	15	20	25

### \*Contents of the Botanic Garden Management Resource Pack include:

*Darwin Technical Manual for Botanic Gardens, A Handbook for Botanic Gardens on the Reintroduction of Plants to the Wild, BGjournal* - an international journal for botanic gardens, *Roots* - Environmental Education Review, *The International Agenda for Botanic Gardens in Conservation, Global Strategy for Plant Conservation, Environmental Education in Botanic Gardens*, additional recent BGCI reports and manuals.

Many of these publications have been translated into Chinese. Please contact us for more details.

I wish to apply for BGCI's **INSTITUTION / INDIVIDUAL** membership (circle one).

Institution Name (if applicable) .....

Contact Name ..... Title .....

Address .....

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Membership category (A-M) ..... Annual rate .....

Please clearly print your name (or the name of your institution) in English on all documentation.

An official invoice will be issued outlining the various payment methods when your membership application has been accepted.

Please contact [info@bgci.org](mailto:info@bgci.org) for further information.

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# BGCI'S FIVE YEAR PLAN

## 2013 - 2018

**T**he global loss of plant diversity with wild places shrinking and plant species facing extinction at an ever-increasing rate has an impact on the global economy and the livelihoods of people worldwide. BGCI aims to mobilize botanic gardens and work with partners to secure plant diversity for the benefit of people and the planet. Over the next five years, BGCI will give greater emphasis to demonstrating the connections between plants and human welfare and on restoring damaged ecosystems, while at the same time continuing our focus on ensuring that threatened plant species worldwide are effectively conserved.



BGCI's ambitious plan for the next five years supports global biodiversity and sustainable development action through three technical programmes:

### **Sustaining wild places and plants**

At least 25% of the world's plant species are presently threatened with extinction and studies indicate that, with climate change, this figure is likely to grow considerably. Significant loss of plant diversity will have catastrophic impacts on human livelihoods. Botanic gardens already cultivate around one third of the world's known plant species and are therefore ideally placed to lead plant conservation efforts. Over the next five years, working in the framework of relevant biodiversity policy, we will continue to focus on securing a future for threatened plant species and their

habitats and will strengthen the coordinated role of botanic gardens in species recovery and ecological restoration.

More specifically, our aim is that by 2018:

- Botanic gardens and the wider conservation community will be able to effectively implement plant conservation policy and strategies, especially the GSPC, linking this to the Aichi Targets and sustainable development policy.
- Comprehensive information on plant species, their status in the wild and in botanic garden collections, is assembled and disseminated in support of plant conservation and restoration actions.



## Finding natural solutions for sustainable livelihoods and human well-being

Wild plants offer a wealth of services and goods of essential livelihood value. Worldwide, over half a billion people who live in poverty depend on the availability of wild plant resources to sustain their daily subsistence needs. However, with the general global loss of biodiversity caused by habitat loss, the spread of invasive species and global climate change, the availability of the range and abundance of plant resources of livelihood value is under threat. Botanic gardens are centres of excellence for research, conservation and cultivation of economically important plants. In support of this, BGCI will publish reviews of work on important resource species, share best practices, support projects to conserve and sustainably use plants valued by local communities and help to conserve the essential knowledge about such plants typically held by local communities.

Our aim is that by 2018:

- The role of wild plants in supporting livelihoods and providing ecosystem services is widely understood.
- Human wellbeing and livelihood requirements, as well as conservation needs are being addressed through more sustainable use of the world's most socio-economically important wild plants.



- Conservation efforts for wild plants and their habitats by botanic gardens and partner organisations are scaled-up and the work of the global Ecological Restoration Alliance (ERA) in replicating best practice worldwide is widely acknowledged.
- The skills and expertise of botanic garden staff in horticulture, collection management, and plant conservation techniques have been increased through training, staff exchanges, provision of relevant information, and networking.

### Connecting people with nature

More than half the world's population live in urban areas and this is leading to a growing disconnection with nature. Botanic gardens offer excellent opportunities for people to experience nature first hand. Collectively botanic gardens engage with more than 250 million visitors annually and have the potential to reach larger numbers and more diverse audiences. Science is at the

heart of modern botanic gardens and botanic gardens can play a key role in developing a scientifically literate society where people are motivated to play their part in resolving environmental issues. Over the next five years we will continue to build the capacity of gardens to connect with growing numbers of people, helping them to reach new audiences, developing scientific literacy and promoting this work widely.

More specifically, we will ensure that:

- All botanic gardens have the capacity to deliver effective environmental education and outreach programmes.
- Botanic gardens understand their social and environmental roles and are increasingly relevant to the communities within which they are located.
- Plants are valued by society and the role of botanic gardens in their study and conservation is widely understood.

# THE NEXT ISSUE OF BGJOURNAL

## PlantSearch:

BGCI's online database of plants in botanic gardens



## GardenSearch:

Your gateway to the world's botanic gardens



The next issue of BGjournal will be published in July 2014. The theme will be: **Using databases to support plant conservation.**

We will be featuring:

- Projects that have used data from BGCI's GardenSearch and PlantSearch databases
- Examples and case studies of botanical databases that have a conservation function
- Articles about the use of databases to manage plant collections in botanic gardens and seed banks
- New methods and technologies for collecting and using plant collection data

The deadline for submitting articles is **15 June 2014**

Please contact **Suzanne.sharrock@bgci.org** for further information.

### BGCI's databases

BGCI maintains two databases: PlantSearch and GardenSearch.

PlantSearch gives an account of the global biodiversity safety-net provided by botanic gardens through a list of the plants they cultivate and conserve. PlantSearch includes over 1 million records, with data uploaded by over 1,000 gardens. It is the only comprehensive global database of wild plant species in *ex situ* collections, and through its linkages to the global IUCN Red List, allows threatened species to be identified in *ex situ* collections. All plant records in PlantSearch are linked to the provider's record in the GardenSearch database, which provides an on-line directory of the skills, expertise and facilities available in over 3,000 botanic gardens around the world.

### Using the databases

BGCI uses PlantSearch to carry out global and regional surveys of threatened species and their occurrence in botanic garden collections as a means to set conservation priorities, as well as to monitor progress toward global conservation targets.

For the botanic gardens that contribute data to PlantSearch, the database provides a useful collection management tool, allowing gardens to identify threatened species from amongst their own collections and also to find out which other gardens are cultivating the same species.

GardenSearch provides important information on the resources, facilities and expertise in botanic gardens around the world in a dynamic searchable form. This is useful for developing partnerships and creating linkages between and amongst conservation practitioners, policy makers, and botanic garden staff alike.

If you have used PlantSearch or GardenSearch data in your research or in your day-to-day activities, we would like to hear from you.

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**BGCI**

*Plants for the Planet*

**Botanic Gardens  
Conservation International**

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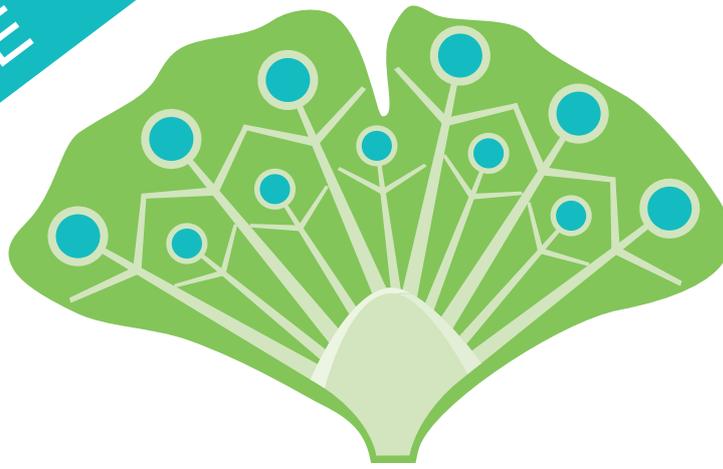
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