Sustaining Transitions and Generating Livelihoods: Lessons from a "Local Production for Local Use" Biodiesel Agro-Booster in Odisha, India

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There has been a renewed global interest on innovations for sustainable transitions due to the impending global climate and energy crises. A key challenge in these debates is in the identification and promotion of technological and institutional innovations that can sustain transitions to a low carbon economy while simultaneously generating livelihoods for local communities. The problem is more acute in many parts of rural India that have little access to affordable forms of commercial energy with low transaction costs, and where agriculture productivity is stymied by a lack of timely inputs. While public policies have in recent times encouraged cultivation of bio-fuels for the market, innovations that seek to use renewable forms within a local or regional village economy continue to lack support due to absence of effective models and capacities at the local level.

This paper will present the case of 'a local production for local use' biodiesel model, which has been nurtured from lab-to-land over the past seven years using underutilized and unutilized raw materials by CTxGreEn,[*] a Canadian not-for-profit organization, in partnership with the Indian NGO Gram Vikas, in the state of Odisha (formerly known as Orissa) in India. Village Level Biodiesel (VLB) comprises a package of village-scale technologies to extract oil from locally available oil seeds, and to refine oil, ethanol and biodiesel. At the heart of the package is a pedal-powered biodiesel reactor that can produce very small batches of biodiesel (5-20L) with one-hour of pedaling. Commercially available diesel engines, running on 100% biodiesel without any engine modifications, are used to power end-use devices such as multi-use power tillers, irrigation pumpsets, mini-oil expellers, rice hullers, *etc*., to provide fee-based agro-services including a range of pre- and post-harvest value addition. The technical design of VLB technologies and processes draw upon principles of green chemistry and green process engineering, targeting 100% product (including by-products such as oil cake, glycerin and soap) and zero waste. The innovation has evolved over time in response to local needs, and has sought to involve various stakeholders through policy dialogues over the years at the regional and state levels. Despite being technologically successful the project has faced institutional constraints due to lack of enabling legal provisions that can further the innovation. Current policy regimes do not encourage local production and processing. Similarly, dramatic changes are needed in the socio-technical regime.

The paper will highlight the innovation journey of the local experiment and situate the niche experiment within larger debates on sustainability regimes. It thus hopes to throw light on the need for greater system innovation in the Asian context. It seeks to bring into the debates on sustainability transitions issues relating to power, knowledge and development urging the need to look more closely at 'who' benefits and what kinds of institutional structures need to be in place for translating the true potential of food and fuel security through biofuels. Such discussions we argue cannot be divorced from the need to generate sustainable livelihoods for *Bottom-of-the-Pyramid* producers, especially those in subsistence economies.

Introduction

On 12 June 2009, a shipment of 9,300 tonnes of biodiesel was sent to Spain from the Indian port of Vishakapatnam. The biodiesel, conforming to European and American specifications, was produced in a facility with a capacity of 273,000 tons per annum, located in the Special Economic Zone of Vishakapatnam, thus benefiting from liberal economic laws. The feedstock used is reported to include soya and palm, both edible oils, and jatropha, a non-edible oil (The Hindu Bureau, 2009).

Around the same time, Kinchlingi a small tribal village with a population of 75 in the state of Odisha, roughly 200 km North of Vishakapatnam, was producing biodiesel from locally grown and harvested niger oil seeds for home-lighting, having earlier used the fuel to pump water for drinking and sanitation. The community of Kinchlingi had pumped over 2 million litres of water over three years using 450 litres of 100% biodiesel in a regular diesel pumpset. The oil used was from niger seeds, typically sterilized and exported to North America as bird feed. Grown and harvested on community land, niger seeds in Kinchlingi

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[*] CTxGreEn is the abbreviated operating name of the Canadian NGO: **C**ommunity-based **T**echnologies E**x**change fostering **Gre**en **En**ergy Partnerships, registered as a Not-For-Profit organization in Kitchener, Ontario, Canada. CTxGreEn works with field-based NGOs in implementing our vision "Local Food and Fuel Security for Global Environmental Security". Further details on CTxGreEn and the Village Level Biodiesel (VLB) project in Odisha can be found on our home page on the web: www.theworkingcentre.org/wscd/ctx/ctx.html

were pressed to produce oil and oil cake. The oil was converted into biodiesel while the oil cake, a ready to use organic fertilizer or livestock feed, was utilized locally.

The production of biodiesel in Kinchlingi started in November 2004 and daily water supply with a biodiesel-fuelled pump-set began in May 2005. In contrast to the 273,000 tpa facility in Vishakapatnam, the village level production unit in Kinchlingi produces biodiesel in 5 litre batches in a pedal driven machine capable of producing up to 10 litres per day and 3,000 litres per annum. And this is achieved with a total investment of less than 300 USD.

The tabling of these two examples of biodiesel production in India would first brook a heated discussion on economies of scale, or, on food-fuel conflicts. What are the other pertinent issues? That policies in India and the world over are focused on centralized large scale efforts, mostly agro-industrial models promoted by and through large corporations that ignore poor farmers and their current livelihoods? Even in cases where farmers have been included, it is mostly for supply of feedstock, encouraging them to move to plantation crops of non-indigenous oil seeds on hitherto food producing lands instead of securing their current livelihoods. There are others who propose that farmers be viewed as rural consumers ripe for tapping by large companies (Prahalad, 2008) – are they just consumers of seeds and fertilizers, or lightning rods for infrastructure development through capital intensive projects? Could the farmer also be viewed as producers creating wealth in the local economy?

This paper will highlight the seven year journey of a local innovation, the Village Level Biodiesel (VLB) technology in Odisha, India, first installed in the village of Kinchlingi, to make a case for greater systems innovation in the Asian context. The paper argues that such innovations, with a large local economy component that cater to livelihoods of small and marginal farmers at the Bottom-Of-the Pyramid, if and when supported, have the ability to balance development and environment agendas while resolving food-fuel conflicts. It is argued that discussions on sustainability transitions through socio-technical innovations, like the VLB technology can not be divorced from the need to generate sustainable livelihoods for the Bottom-Of-the-Pyramid producers especially those in subsistence economies (Karnani, 2007; Yap, 2008).

Experience also shows that innovations such as the VLB technology are out-of-sight and below both the radars of policy makers as well as the free market (Hall, 2010) and so have difficulty in garnering needed support. The paper will bring into the debates on sustainability transitions issues relating to power, knowledge and development, urging the need to look more closely at 'who' benefits and what kinds of institutional structures need to be in place to ensure that the true potential of food and fuel security through biofuels is harnessed fully.

Biodiesel as it pertains to the VLB

It is important at the outset to distinguish the Village Level Biodiesel (VLB) as a *local production for local use* model that (a) is unique and differs in scope and intent from conventional biofuel initiatives, and (b) targets food-and-fuel-security at the local level.

Biodiesel as it pertains to VLB is produced and used at the point of production or within a 15 km radius, hence the classification of the VLB as a *local production for local use* model. The scale of production is small and the feedstock used are indigenous oilseeds that are underutilized or even unutilized locally. There is therefore no question of plantation fuel crops displacing food production, or fuel for transportation undermining the food security of farmers (numerous reports have flagged food-fuel conflicts inherent to large biofuel projects, including FIAN, 2008; OXFAM, 2007; UN Energy, 2007; Hazell and Pachauri, 2006).

Biodiesel as it pertains to VLB is not used to fuel mass transportation. The emphasis is not on substituting existing fossil fuel consumption but in augmenting development, especially in infrastructure starved areas, and that too without causing any net increase in greenhouse gas emissions.

The focus of the VLB is therefore on enabling the provision of agro-services in remote rural areas that do not have easy access to diesel. Typical end-use devices include multi-use power tillers, irrigation pump-sets and small diesel engines to power mini-oil expellers, rice hullers, *etc*. The idea is to make use of commercially available diesel engines, without any modifications, and with the support of existing dealer networks.

Biodiesel fuel as it pertains to VLB is thus produced by the chemical transformation of vegetable oil in the presence of alcohol and lye, also known as transesterification. Absolute or dry alcohol containing < 0.5% moisture is required for the reaction, but it could either be methanol, or ethanol produced from locally under-utilized fruits. The lye can be either sodium hydroxide (NaOH) or potassium hydroxide (KOH) of commercial purity and low in moisture.

Figure 1. Pedal-powered Biodiesel reactor (capacity: 5 litres per batch)

Biofuels and Engines that burn Biofuels.
All fuels derived wholly, or even partly, from plant biomass qualify for classification as biofuels. There are gaseous biofuels like biogas and producer gas, and there are liquid biofuels like bioethanol and biodiesel. All such biofuels are combustible in internal combustion (IC) engines.

There are two types of IC engines: (a) spark-ignition engines that are fuelled by petrol or gasoline, and (b) compression ignition engines fuelled by diesel. Biogas, producer gas and bioethanol are highly inflammable fuels and require spark ignition engines modified to match the characteristics of specific biofuel. Diesel fuel (also known as high-speed-diesel or petro-diesel) and biodiesel are both non-inflammable under normal conditions, and so require "compression ignition" engines.

The term biodiesel itself is often used rather loosely to include: (1) 100% pure vegetable oil or straight vegetable oil (SVO), (2) Blends of diesel with 5% to 10% SVO, (3) 100% pure transesterified biodiesel, and (4) Blends of transesterified biodiesel and diesel, specified as B5, B10, *etc*., where the number after "B" denotes the per cent biodiesel in the blend.

Diesel blends containing less than 10% SVO can be burned in standard diesel engines, but SVO requires significant engine modifications, and dual fuel tanks. 100% pure transesterified biodiesel (B100) that conforms to standards does not require any engine modifications, and will perform well in a standard diesel engine as long as fuel hose-pipes and fuel filter are devoid of natural rubber components, and ambient temperatures are reasonably above freezing.

Four Hours to Fuel: The village-scale biodiesel reactor produces biodiesel in small, five-litre batches from a combination of vegetable oil, lye and alcohol. Five minutes of pedaling combines the lye and alcohol into a homogenous solution in a small stainless steel mixer. This solution is added to vegetable oil in a larger stainless steel reactor. An hour of pedalling converts the oil-lye-alcohol mixture into biodiesel and glycerine. A by-product that can be turned into soap, glycerine has a higher density than biodiesel and separates within two hours. In total, the production process takes about four hours, including one hour of pedaling. (Vaidyanathan, Sankaranarayanan, 2009)

In the VLB model feedstock for vegetable oil is locally available and currently unutilized or underutilized oil seeds that are either collected from the forest (*e.g.*, mahua or Madhuca *indica*, karanj or Pongamia *pinnata*) or grown in family farms as short duration crops (*e.g.*, niger or Guizotia *abysinnica*, linseed or flax seed or Linum *usitatissimim*). The seeds are cleaned and dried before being pressed into oil. The residual oilcake, left over from pressing the oil can be used as organic fertilizer and in some cases as livestock feed.

The pedal-powered biodiesel reactor shown in Figure 1 above is well-suited and sized for small remote non-grid villages. Each batch of biodiesel requires only about 5 litres of oil, which could be produced from 20 kg of oil seeds. In its simplest configuration, requiring four hours to fuel as explained in the box above, this biodiesel reactor will produce 50-60 litres of biodiesel each week, enough to keep a power tiller fully engaged. The weekly production could very easily be increased as long as the raw material supply and biodiesel demand warrant it: (1) the addition of a glycerin settling tank will halve the time to fuel to two hours, doubling the weekly biodiesel production and the number of power tillers supported; (2) the same pedal-powered drive has been designed (and already proven) to support a 20-litre reactor, which could mean a further quadrupling of weekly production to 500 litres and raising of the number of power tillers supported to eight or even ten. (Provision has also been made to accommodate a small ½-HP electric motor that will substitute for the pedal drive should the production volumes justify the installation of a generator).

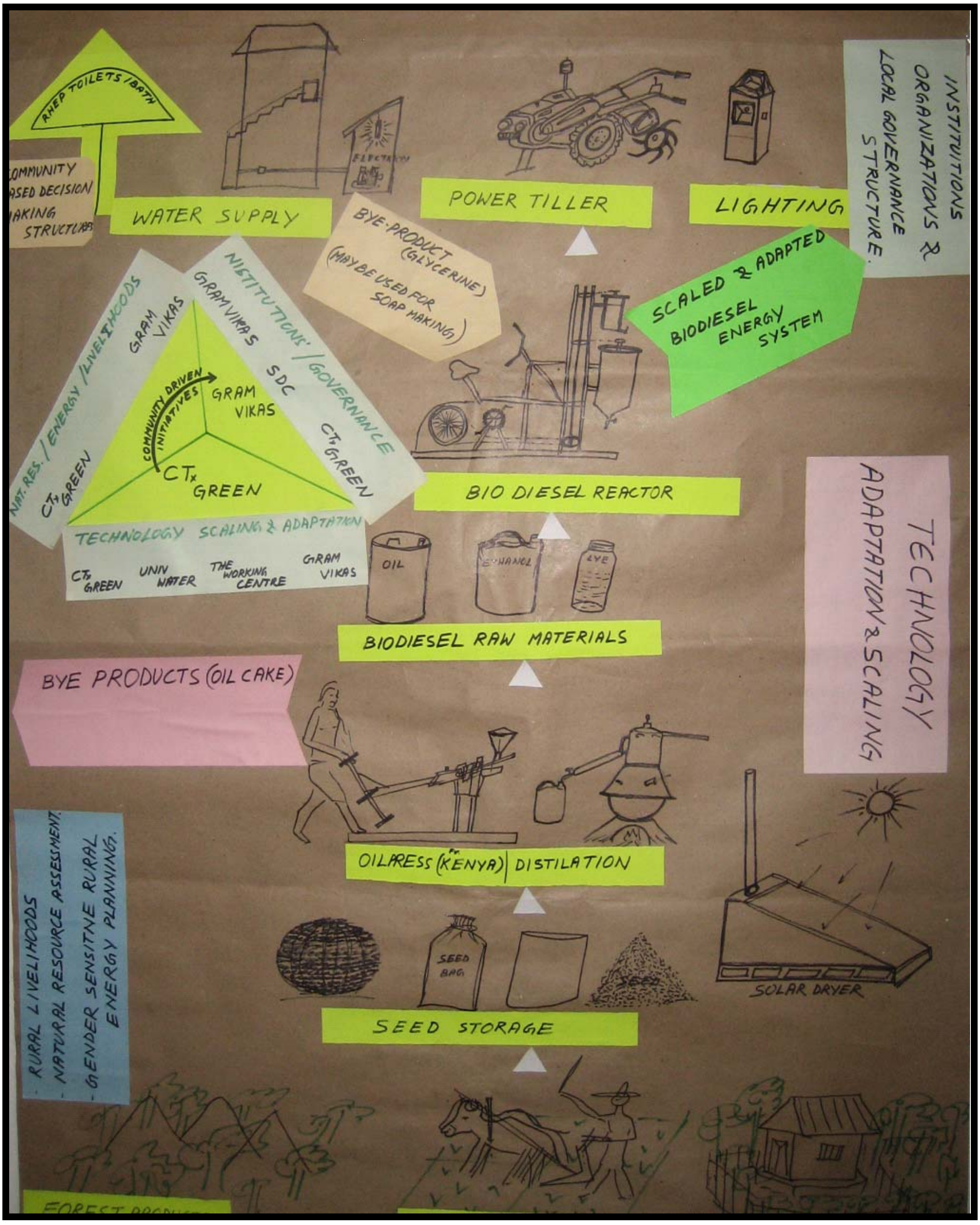

Figure 2: A schematic depiction of VLB model showing material flows (raw materials, products and by-products), production processes, services enabled, and stake-holder roles.

The output of each VLB biodiesel reactor is thus capable of supporting a substantial amount of agro-services and mechanization in clusters of villages with sufficient quantities of oil seed feed stock. The other advantage is that locally pressed oilseeds mean that the oilcake is available as input into the fields as an organic fertilizer, thus stemming the outflow of nutrient from the local ecosystem. Biodiesel produced in this manner maximizes local value addition and has the lowest cash outflow from the village economy.

The cascading potential of the VLB technology: using the biomass for various uses and the wastes for energy, as well as the enhanced possibilities for carbon sequestration by storing soil carbon, opens a whole new dimension of looking at biodiesel production (UN Energy 2007).

Context for the VLB technology

Indigenous tribal communities living in remote infrastructure-starved villages of Odisha, in the South East coast of India in sub-humid agro-ecological zone, form the immediate context for the development of VLB technology.

Odisha is well endowed with natural resources, yet it is one of the poorest states in India. Rich in mineral resources, and a net exporter of electricity, Odisha[3] is considered one of States that are *least food secure* in India. With a population of 40 million living in 155,707 sq.km., Odisha accounts for 4.9% and 4% of India's geographical area and population, respectively. Agricultural statistics published by the Odisha government indicate a surplus rice production of 17%, in 2006-07, after accounting for seed, feed and wastage, and *allowing* for the entire population's consumption of the daily recommended requirement of 400g rice/adult. Subsidized rice is also distributed to those living **b**elow the **p**overty **l**ine (**bpl** families are eligible to purchase 35 kg of rice per month at Rs.2/kg). Food security should not have been an issue. But it is, mainly because of the lack of access to land and tenure, water and other inputs, economic opportunities and purchasing power, *etc*., all of which are critical to food security.

Indigenous people (Scheduled Tribes or ST, 22.1%) and other disadvantaged groups (Scheduled Castes or SC, 16.6%) make up 38.7% of the Odisha population. A majority of the 8.9 million indigenous tribals of Odisha continue to live in their ancestral lands, among the hills and forests, without much access to basic infrastructure such as roads, electricity, diesel and emergency medical care.

First deprived of their rights when the British Raj confiscated all forests as government land (and restricted their access as per designation of reserve and revenue forest, and so on), the tribals are yet to regain full access to their ancestral land. Recent legislations such as the Forest Rights Act (2006) are designed to enable better access to their land, but much remains to be done. Many tribals continue to practice shifting cultivation (known as *bogodo* in Odiya language) on sloped land in hilly terrain; they clear trees by slashing and burning, the ash meant to lend soil fertility for a growing season or two, before they have to move to another location and repeat it all over again.

Nutritional diversity is very high in the tribal diet, as they grow up to 22 varieties of grains, pulses and vegetables in their *bogodo* plots, but this form of subsistence agriculture does not fully meet their needs any more. To make up the shortfall, and to raise money to buy edible oil, clothing and other essential items, they collect forest produce (among them are tree-borne oil seeds) and sell them, often at prices bordering on distress sales, to traders who double as money lenders in times of need. Many tribal men migrate to far-away cities in search of wage labour, often pulling 12-hour days of hard work for wages that appear to be princely sums compared to earnings back home. But higher expenses in cities also mean that net earnings barely match those at home, where women end-up fending for themselves and their children alone; and much of the homestead land remains fallow for lack of farm hands to cultivate.

[3] Odisha is a state in eastern India, formerly known as Orissa..

Some tribals grow oil seeds too, but mostly as a cash crop, and later, like every other tribal family, buy edible oil in small weekly quantities at prices much higher than if they could have converted their own oil seeds locally into oil. Several tribal villages have been resettled by NGOs including Gram Vikas, along valleys served by rural roads. Land tenure continues to be an issue with such resettled tribals; while there isn't enough land to meet essential needs, medical care is nearer.

Agricultural statistics, however, reveal a net deficit in the production of pulses and oil seeds: the gap between production and estimated consumption (calculated from "daily requirement") is 2 to 5% for pulses and >15% for oil seeds. More importantly, the kg/hectare productivity of most crops, including rice, is 15-30% lower in Odisha compared to All-India averages.

Other statistics are even more dismal: promotion of mixed cropping has been a State priority to improve land productivity, but coverage continues to hover around 1% of all cultivated land; electricity consumption in agriculture is 2% of the total; less than 40% of the land is irrigated (two or even three crops are possible each year under irrigated conditions in the same piece of land; only one crop is grown in 60% of rain-fed/rain-dependent land). When monsoon rains fail, as they did in 2002-03, agricultural output takes a severe hit.

Increasing the level of agricultural mechanization is a priority for the State and Central governments, yet less than 15% of all agriculture in Odisha is mechanized. With a shortage of farm labour and draught animals, it means that loss of agricultural yield related to delayed (tilling and) sowing may be significant.

The VLB technology as it stands today caters to this niche through locally produced biodiesel to fuel tillers that provide agro-services on wheels. Timely sowing and tilling, second crop irrigation and the availability of oil cake as organic fertilizer can contribute to enhancing agricultural productivity.

The evolution of the VLB technology

The VLB technology was initiated in three infrastructure-starved remote communities dependent on the forest to supplement subsistence forms of agriculture, through seed funding from the World Bank Development Marketplace Awards, DM2003. The winning entry for DM2003 that targeted making services available for poor people was titled 'Carbon Neutral Biodiesel Fuelled Energy Services for rural water supply and santiation (www.developmentmarketplace.org/...)." The project was implemented by CTxGreEn, a Candian Not for Profit, in partnership with Gram Vikas, an Indian Non-Governmental Organization. CTxGreEn fosters green energy partnerships with the vision of enhancing global environmental security through local food and fuel security. Gram Vikas is voluntary sector organization that has been working in the state of Odisha since 1979. Their current focus is water supply and sanitation for rural habitations as a part of their Movement and Action Network for Transformation of Rural Areas, MANTRA.

Starting with the pilot plant at Mohuda (which is also doubling as a resource centre for biodiesel), biodiesel production units were established in Kinchlingi, in Nov 2004 and in the twin villages of Kandhabanta and Talataila in December 2004 (Table 1).

While a (bio) diesel pump set was installed in Kinchlingi (population 75) early in February 2005, daily water pumping could start only in May 2005 after completion of the water tank in the village. In spite of several challenges, the village of Kinchlingi ran the biodiesel pump set daily for one hour, for over three years, using more than 450 litres of biodiesel to pump over 2,191,418 litres of water, until gravity flow arrived in April/May 2008. The village wanted to retain VLB in the village for another two years, in spite of now having an alternative water supply, as insurance in case the gravity source and the stream supplying their village went dry. In consultation with the CTxGreEn-Gram Vikas team, the village decided to use the equipment for providing lighting. The change over took over 6 months, and in January 2009 biodiesel was used to run a generator and provide lighting to the village of Kinchlingi.

In the second set of villages, Kandhabanta and Talataila (population 151), a (bio) diesel pump set was not suitable since the water table dips below 40 feet in summer. A biodiesel-fuelled generator set was required to generate electricity that would drive the ½ HP submersible pump. Biodiesel-fuelled water supply started in July 2006 in Kandhabanta-Talataila and continued for about 10 months, during which period water was pumped and supplied for 135 days, consuming approximately 90 litres of biodiesel. Over 130 kWh of electricity was generated and 488,000 L of water were pumped in KBTT. The biodiesel-fuelled water pumping system has since been replaced by a gravity-flow water-supply system. Biodiesel pumping can be used in the summer months when the streams run dry. In addition the community would now like to use biodiesel for home lighting.

Table 1: The first two village-level biodiesel installations in two tribal villages in Orissa since 2004

Village	**Kinchilingi**	**Kandhabanta-Talataila**
Households	**15**	**32**
Management model	"Sweat equity" Each household provides one volunteer, one day per month to run and maintain the biodiesel reactor with the assistance of a barefoot technician.	Operated and managed by the Women's Self Help Group (SHG) with the assistance of a barefoot technician.
Biomass source * Niger introduced as new crop. A stop-gap raw material for biodiesel until tree-borne oil seeds become available from forest, after which it will become an edible oil crop.	o Volunteers cultivate by rotation, 4 acres of niger*(edible indigenous oilseed) a short duration, 120 day non-intensive crop on fallow land (not cultivated for >3years) + exchange salt with hilltop village for karanja (non-edible oil seed). o Oil pressing by sweat equity after the harvest	o Volunteers cultivate by rotation, a 5 acre, 120 day, non-intensive niger* crop in community fallow land (never cultivated before). o Oil pressing as a collective activity after the harvest.
Consumption of biodiesel fuel	o 11 to 13 litres / month from May 2005 to April 2008 for water supply. o 700 hours of pumping; 470 litres of biodiesel. o 13 litres / month for hybrid lighting: Jan 2009-	o ~13 litres / month Jul - Aug' 06, Dec'06 - May' 07. o 153 hours of pumping; 88 litres of biodiesel.
Equipment fuelled by biodiesel	o 3.5 HP biodiesel pump-set for water since May 2005. o 3.5 HP gen-set based hybrid electrification scheme; since Jan 2009 : 1 hour of 220V mini-grid and charging of a battery bank for extended hours of LED lighting.	o 3.5 HP biodiesel generator running a 1/2 HP submersible electric pump-set.
Direct benefits 80% of the cost of biodiesel is for seeds and oil expelling	o 2,200,000 litres of water supplied over 3 years using biodiesel until gravity-based system was introduced in 2008. o Village Electricity Committee responsible for 60kg/month niger for biodiesel and Rs.30/month/family as tariff for biodiesel-fuelled hybrid lighting with LED+220 volts 15W CFL. o Fuel for a multipurpose tiller to facilitate cultivation. Demonstrated profit > Rs.500/day after paying wages for two semi-skilled people and deducting O&M costs. o Women freed from fetching water are being motivated to run glycerine-based soap making as a business activity in their Self Help Group, Bhairabi.	o 500,000 litres of water supplied over a 7 month period, until gravity flow was introduced in 2007. o Women, freed from fetching water, can now participate in income generating activities. o Niger becomes an edible oil crop locally.
Future plans	o Biodiesel supplied through the Bhairabi Self Help Group could fuel multipurpose tiller for a second yearly crop (b) small post-harvest equipment like rice-hullers and (c) a large oil expeller. o This will generate at least 10 direct jobs, enhance the income for self help groups and **double the food production**. In a cluster of 20 villages, with more than 300 farmers.	o Use of a biodiesel fuelled **multipurpose tiller**, generator charged LED mobile lighting. o Niger inter-cropped with a legume or pulse crop on community fallow land, enhancing agricultural income two-fold while improving soil-nutrition.

In the third area of implementation, Tumba, CT_xGreEn and the Gram Vikas field teams worked closely with the villagers in three clusters of villages (totaling about 48 villages in all) assessing underutilized oil-bearing trees in the forests. Over 3,000 oil seed bearing trees are available in one cluster alone, and it is estimated that there are over 20,000 trees that bear about 375 tonnes of seeds, in the entire Tumba area (see Table 3). A livelihood proposal was developed for VLB technology in the community, with watershed management as the first activity in one cluster of about 8 villages, slowly including other neighboring clusters. The community in Tumba has identified small livelihood activities like oil expelling and water pumping for irrigation as the niche for using biodiesel. Work in Tumba now includes about 48 villages, 21 of these being areas where Gram Vikas has been working for over 15 years and the rest being contiguous villages. The work in Tumba was informed by lessons from the Kinchlingi village and the Kandhabanta-Talataila villages.

Biodiesel has been developed from different oilseeds, *viz* niger (Guizotia *abyssinica*), karanj (Pongamia *pinnata*) and mahua (Madhuca *indica*), at the pilot plant at Mohuda. Another role of the pilot plant is to develop good operating practices to manage and monitor the technology and its impact on the community. The thrust over the last two to three years has been to train barefoot technicians (usually 7th and 8th grade drop-outs) from the local community to monitor quality of the fuel, operate and maintain machines, log data and most importantly run the unit as a sustainable enterprise providing agro-services and local value addition through oil expelling activities.

Besides the training and process development functions, in 2009, the Mohuda pilot plant serviced 23 farmers in the neighborhood by providing timely ploughing using a multipurpose power tiller. The purpose was to demonstrate the potential for biodiesel to provide agro-services on wheel.

The approach of the CTxGreEn in Odisha has thus been different in the three geographical areas. The Kinchlingi project, launched within the first three months of project initiation, had a technology focus, leaving most of the community development effort to the local Gram Vikas team. In the twin villages of Kandhabanta-Talataila there was discussion around the management structure, and a workshop was held with the villagers to map their community resources and develop a micro energy plan based on availability of feedstock and demand for energy services. Most of the community mobilization was again left to the Gram Vikas field staff, but with active support from the CTxGreEn team on an as-needed basis. Both the earlier sites were suggested by Gram Vikas and pursued in spite of insufficient useful feedstock: Kinchlingi because a village-level demonstration site was required that was easily accessible, and Kandhabanta because it was a forest village with access to sal seeds, a feedstock that later turned out to be non-starter for biodiesel as it does not yield oil through mechanical oil expellers but requires high-tech solvent extraction.

In contrast, Tumba epitomized the ideal site for the application, being remote and having ample forest seeds. In addition it has the indigenous agro-oilseed niger, which is not locally used but sold to middlemen for about Rs. 16 per kilogram. The communities in Tumba, the Saura tribals, are dependent on the forest for their livelihoods. Besides the sale of minor forest produce, their mainstay is a form of slash-and-burn agriculture called *bogodo*. This form of subsistence agriculture promotes multiple high nutrition crops and is a low-input agriculture, but is not sufficient in meeting their food requirements. Residents of the Tumba cluster face food shortages and seasonally migrate to cities. There is almost no infrastructure available in the form of roads, electricity, primary health services or any form of communication. Residents trek down anywhere an elevation of between 300 to 500 metres (over 9 km downhill) and then walk another 10-15 km on the plains for supplies not produced in the village, and then make the return trip back to their hill-top residences. Gram Vikas has been working in 21 such villages since the 1990s through its integrated tribal development program. CTxGreEn initiated work in the Tumba cluster in June 2004 through an intensive survey of the forest, followed by an inventory of oil-bearing trees in 2005-06. A study of *bogodo*, the local traditional agricultural system, was also conducted through a participatory workshop with five farmer families in August 2004. This was a preamble to the more involved activities that were to follow.

Collaborative knowledge exchange for sustaining technology transition

Initially targeting three communities, the CTxGreEn project has been on a very slow upward spiral, adapting constantly to the changing needs of the villagers. Village Level Biodiesel technology is currently being aimed at the provision of agro-services and livelihood in rural communities and as a 'local production for local use' model. The non negotiable aspects of the model that remain unchanged are (1) village scale production and local use and (2) use of only unutilized and under-utilized oil seeds for biodiesel production. With such a focus on decentralized microenergy utilization, technology is only one of the five components of the model (see Figure 3). The other four components are: (ii) natural resource assessment and monitoring for sustainable resource utilization, (iii) rural energy planning to understand community energy needs, (iv) institutional analysis to identify local stakeholders to anchor village level biodiesel as an integrated package and (v) policy demystification, advocacy and lobbying to facilitate local integration of the model. VLB implementations in the three communities have had different emphases, as described in Table 2 below.

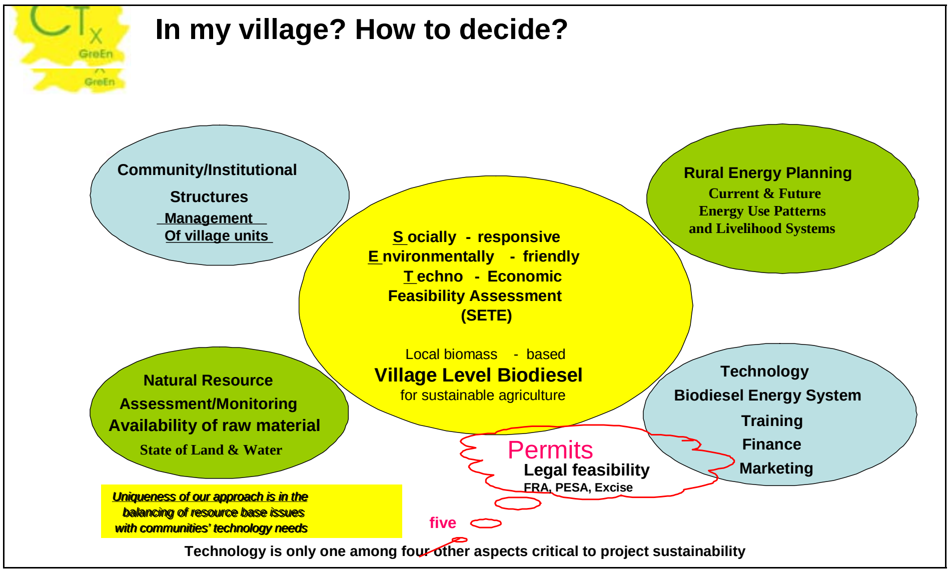

Figure 3: Five components of the Village Level Biodiesel

Table 2: Five components of the Village Level Biodiesel model

	Kinchlingi	KB TT	Tumba
Natural Resources	➢ No forest seeds or private land. ➢ Community land used to grow short duration Indigenous oil seed crop	➢ Shorea Robusta, or sal seeds available in forests, not suited for producing biodiesel at the village ➢ Large tracts of community fallows, useful for short duration indigenous oil seed crop	➢ Reserve and village forest with large quantities of tree-borne oil seeds suitable for biodiesel prod'n. ➢ Private farmers growing niger, a potential biodiesel feedstock currently exported as birdfeed ➢ Community fallows available to grow oil seed crops
Rural Energy	➢ Water supply was the initial focus, followed by ➢ Home lighting	➢ Water supply was Gram Vikas' focus but women were interested in livelihood applications & cooking fuel	➢ Agricultural services like water pumping, livelihood applications like oil expelling and rice milling
Institutions	➢ Entire village was involved: a volunteer driven 'sweat equity' model managed by a local barefoot technician	➢ The Self Help Group was the focus, managed by a local barefoot technician.	➢ Self Help Group and farmers cooperatives supporting local enterprises
Policy	➢ Panchayats Extension to Scheduled Areas (PESA), 1996	➢ Excise policy for waiver of duties for input materials required to make biodiesel	➢ Forest Rights Act (FRA), 2006
Technology	➢ 5L pedal driven biodiesel reactor ➢ 3.5 HP biodiesel pumpset, ➢ 10kg/hr manual oil press ➢ Battery charged by biodiesel generator, and ➢ LED lanterns	➢ 5L pedal driven biodiesel reactor ➢ 3.5 HP biodiesel generator ➢ ½-HP submersible pump ➢ **10kg/hr manual oil press**	➢ Oil press ➢ Oil expeller coupled to multipurpose tiller ➢ 20L biodiesel reactor

The VLB technology was introduced in each of the regions based on an understanding of the local context in terms of both the community needs as well as ecosystem characteristics. A process of technology optimization was done even before introducing it in the villages. This was done in collaboration with the concerned community members who were involved in giving inputs to the technology even as it was being adapted. Depending on the people and resources (actors, resource base characteristics, local institutions and organizations and their inter relationships), livelihood strategies were developed separately for Kinchlingi, KBTT and Tumba. The expected outcome was aimed at reducing vulnerability of the community and the ecosystems and contributed to a modified context but more uncertainty and unpredictability (see Figure 4). In order to sustain this transition to the new technology, the VLB technology had to be modified to suit the new context. The entire process continued to be iterative and has now evolved into what has been described as a well-developed adaptation approach to climate change.[4]

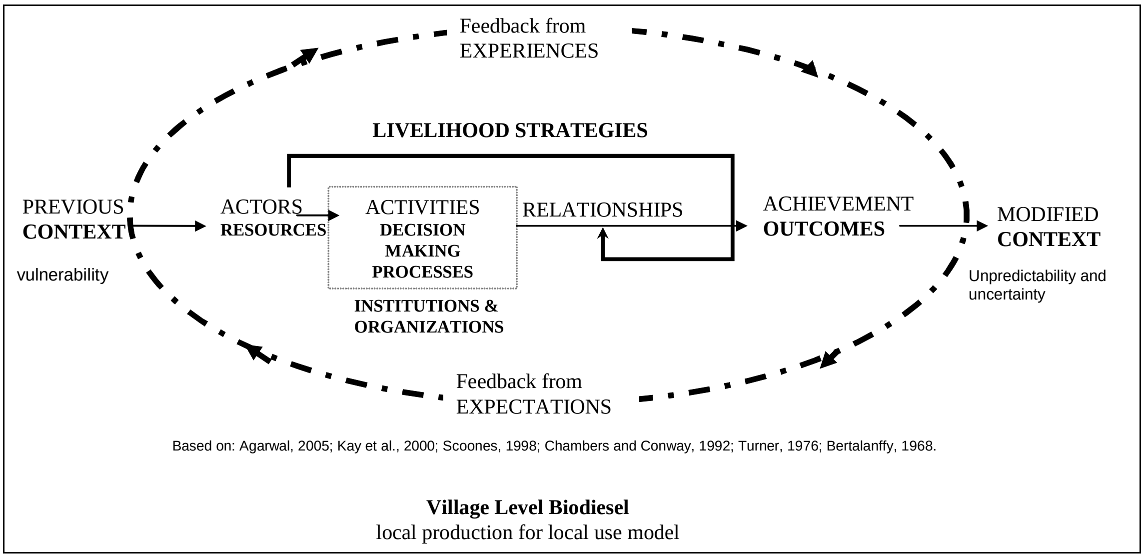

Figure 4: The iterative loop of technology adaptation adopted by the Village Level Biodiesel in Odisha (Vaidyanathan 2009)

The project was launched in Kinchlingi within the first three months of the DM 2003 phase and was aimed at proving that the community as a whole could handle the technology. In the first village of Kinchlingi, the focus was on evolution of the technology. Biodiesel was initially used in a pump set for water pumping, and later in a generator to provide lighting. The village adopted a volunteer model, and over the four years validated the techno-economics of VLB. The case study highlights the technology-community relationships, including the role of women in promoting technology acceptance. The focus of the Kinchlingi phase of VLB was the adaptability of the technology.

In the second community, the twin villages of Kandhabanta and Talataila, KBTT, emphasis was on involving women from Self Help Groups and to expand the potential use of biodiesel beyond water supply in the long term. The configuration of the technology was different from Kinchlingi and included a generator and an electric pump in place of the diesel pump. The context of KBTT was more complex involving two villages, Kandhabanta and Talataila, half a km apart. The challenges of dealing with changes in the technology specifications, coupled with a different management system, led to a strategy that was different from Kinchlingi. The cost of water supply was calculated based on the data generated from running the unit in the village, and was found to be marginally lower than Kinchlingi. KBTT is better suited for VLB in terms of resource base characteristics. Yet technology innovations assessed for KBTT were finally implemented in Kinchlingi, because of the readiness of the community in Kinchlingi. The Self Help Groups in KBTT need to be strengthened in order to take up their role in the management of VLB. The Village Executive Committee and the forest protection

[4] Personal communication, to Ramani Sankaranarayanan by Dr. Othmar Schwank, Managing Director of INFRAS, 2008, during a discussion post presentation at side event at the Convention on Biological Diversity, CBD, Bonn.

committee (*Van Surakhsa Samiti*) also have a role in the management structure of VLB in the Self Help Group model. A cluster approach including five neighboring villages is proposed for the way forward. The case of KBTT is an example of how a good plan can get compromised during implementation.

In Tumba, the third area, a remote cluster that nurtures a subsistence forest based community and has poor infrastructure links, the focus was on an integrated approach of matching community energy needs to availability of resources. A three pronged approach of (1) biodiesel fuelled livelihoods (tilling, irrigation), (2) local value addition (oil expelling to sell oil instead of seeds) and (3) sustainable agriculture (use of oilcake as fertilizer).

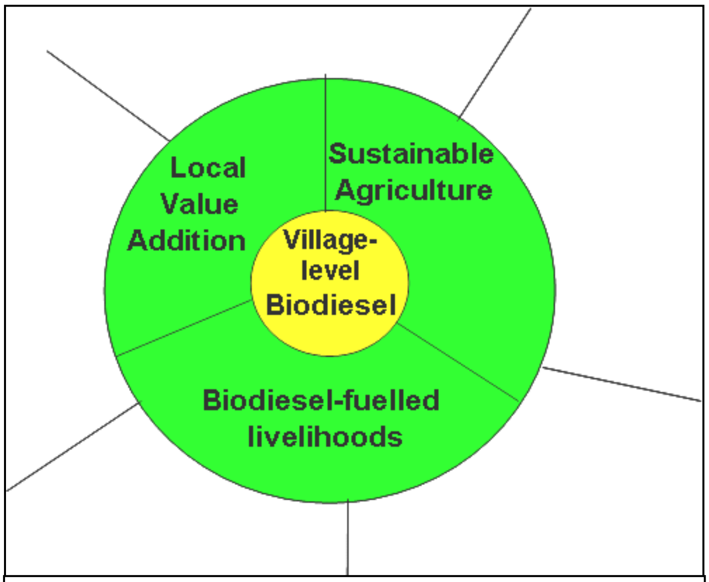

Figure 5: Three-pronged approach adopted in Tumba

The case of Tumba was different again, firstly because it involved three separate clusters (totaling about 48 villages), and secondly because VLB technology for biodiesel production has not yet been installed here. The current emphasis in Tumba is on setting up an oil expelling enterprise, privately owned but supported by SHGs. It is proposed that the SHGs could act as an interface between the market and the banks and reduce the risk to the oil milling entrepreneur. Strengthening the SHGs to take up this role, and to effectively reduce the outflow of their oilseeds by value adding and using oil and oil cake locally, is needed for the success of VLB in Tumba. The oil expelling enterprise is based on a multipurpose biodiesel fuelled tiller. The tiller is expected to provide agro-services in the form of tilling, mobile water pumping and harvesting during the agricultural season. The tiller engine can also be used for running an oil expeller or a grain mill, thus being a multiplatform biodiesel fuelled device.

It is estimated that it is possible to produce about 100 kL of biodiesel per annum with the available seeds in the Tumba cluster. There is therefore potential for not only promoting a second crop and converting oil seeds to oil locally, but also to bolster subsistence activities like cooking and lighting thus offsetting fuel-wood and kerosene respectively. All these activities, it is estimated would require about 150L of biodiesel per day, which could amount to a reduction in CO_2 emission of approximately 10 tonnes per day (Table 3).

The proposed implementation in Tumba with 48 villages and a total of 1500 households is a first step towards scaling up of activities to include livelihood activities, especially those that boost agriculture. It is also the first step towards scaling out of activities of the VLB technology to other parts of Odisha.

A capacity building workshop was conducted in May 2010 with 40 representatives from 12 NGOs in Odisha with the view of carrying out feasibility studies for the replication of the VLB technology in their areas of operation. These NGOs are spread over 9 districts of Odisha. Initial study results indicate the potential for replication in at least 6 districts, with the focus on sustainable agriculture and local value addition assisted by biodiesel fuelled livelihoods.

Table 3: CO_2 Red'n Estimate for cluster of 50 villages; 30 hh/village (average); 1500 hh/cluster - Tumba

	Details on Biodiesel production/consumption	BD L/day	BD L/year	**Notes and assumptions**
	Total BD production potential from 20,000 trees, 375 t seeds, 277.5 t of oil cake (available for agriculture)		~100 kL	25kg/tree/year (average), 75% trees bearing fruits/year, 25% oil yield, BD (0.87g/cc density; *i.e.*, 5kg oil- 5.75L BD)
	Total BD Consumption Potential	150.4 L/day	43,350 L/year	
Sl. No.	**CO_2 Reduction Potential by Item**	**kg CO_2 / day**	**t CO_2 / year**	**Notes and assumptions**
1	Avoided Kerosene for home lighting	480	174	50 villages; 1500 hh/cluster
2	Avoided Diesel for Gen-set-LED Lighting	160	58	1500 hh; 2 LED/hh; 18.25 kL BD/y
3	Avoided Urea: Use Oil cake as fertilizer	152	56	925 acres; 55.5 tonnes avoided urea
4	Avoided Slash&Burn acres (replantation?)	9,107	3,324	750 acres 'avoided slash&burn/year'
5	Avoided Diesel for BD-fuelled Oil Expelling	109	40	20000 trees; 375t seeds; 12.5 kL BD/y
6	Avoided Diesel for 2nd crop irrigation	110	40	1500 acres; 12.6 kL BD/y
7	Impact of 1,500 acres/year replantation			not included
8	Avoided firewood (usu. Collected in slash & burn)			Biodiesel stoves for cooking - not incl.
	Total CO_2 Reduction Potential	**10,118**	**3,692**	
	Subset of above: CO_2 Reduction Potential w/o including Slash-and-burn credits	**1,011**	**368**	avoided slash-and-burn credits constitute more than 90% of 'total (not including biodiesel stoves for cooking and plantation credits)'

Transitions to the VLB

The VLB journey has been one of adaptive change, adjusting the technology to the socio-cultural demands while struggling to incubate it in local institutions. Introduction of such new forms of knowledge that collaborates with the vernacular makes the already involved process of technological change even more complex. Rural innovations focused on local livelihoods have to go through a phase of regeneration and creative destruction (Schumpter, 1945; Holling, 1995) constantly reinventing themselves while adapting to the changing needs of the community. The VLB technology was initiated for providing piped water supply and later home lighting. Today it is being promoted as a fuel for agricultural mechanization because it became evident along the way that communities at the Bottom of the pyramid are more likely to make investments of time and money for livelihood enabling technology than for subsistence activities like drinking water and cooking especially when they can collect water from a nearby stream or well and fuelwood from the forest at no cost. It also became evident that transition to renewable energy technologies for rural innovation can only be sustained by socio-technical as well as institutional innovations that support the technology adaptation process and nurture local delivery systems. The role of supportive policies can not be undermined.

With the 73rd amendment to the Constitution of India (1993), there has been devolution of power to the grassroots. The practice of decentralised decision making, however, is only slowly becoming a reality. In keeping with the drive to build an informed civil society at the grassroot, there are several provisions in the existing policy regime that can be instrumental in making the transition to decentralised energy production easier.

Biodiesel Policy in India

India has a national policy on biodiesel and every province has also been encouraged to develop their respective policies. Although the Government of Odisha is the first in the country to have a biodiesel policy in place (GoO, 2007), it has been formulated keeping in mind the jatropha based agroindustrial large scale models aimed at providing fuel for transport . The policy of the province of Odisha outlined under the “Policy guideline on raising energy plantations and biodiesel production, (GoO, 2007),” estimates that there is potential for 14,000 KL of biodiesel / annum in the province which could utilize 0.6 million ha of wasteland, and generate 100 million person days of employment and 42,000 tons of organic manure. There is a big emphasis on the promotion of jatropha, a non-indigenous species. Although the policy explicitly states that only wastelands will be used for cultivation, the subsidies being made available are easing out food crops in many parts of the state, enough to have raised a hue and cry from local activist groups (FIAN, 2008). The policy contains the following provisions on the small-scale biodiesel production (GoO, 2007, Section 7.0, p.5 of resolution 5345, dated 23Aug07):

1. Small biodiesel production centres will be encouraged in rural areas for different local applications like water pumping, village electrification, *etc*.
2. There is no minimum size for a biodiesel facility and small decentralized biodiesel facilities do not require dedicated technical staff; they can be operated by locally-trained non technical staff
3. The Indian Oil Corporation (IOC) has agreed to buy the entire biodiesel yield produced in the state, subject to quality and regulation of supply.

There is no reference to (a) livelihoods, (b) local production for local use or (c) tax exemptions for purchase of alcohol. Nor are there any provisions to assist the “small biodiesel production centres,” although there is a lot of emphasis on facilitating credit for raising jatropha plantations and linkages with the bank National Agricultural Bank for Agricultural and Rural Development to obtain the same. The role of farmers in the proposed scheme is only to provide the raw material, and their training is limited to learning how to raise the plantations. Processing centres are envisaged as large-scale units: the oil expeller proposed in the ‘model seed procurement centre’ (GoO, 2007, p11) has a capacity of 5 tpd and runs on a 40HP motor. It is easy to see that when the discussion is around 5000 kg of seeds per day, an 80 kg per day unit feeding a 5L/batch biodiesel reactor in a VLB system appears insignificant, even though economically more viable.

Even the newly drafted National Biofuel Policy (MNRE, 2008), approved by the Union Cabinet on the 11 September 2008, is premised on “an indicative target of 20% by 2017 for blending by biofuels.” There is emphasis on the use of degraded marginal lands for biofuel plantations and on use of non-edible oilseeds. Only indigenous feedstock is permitted for use in biofuels and there is no allowance to import oil. Yet the policy is silent on the concept of local production for local use. The Ministry of Petroleum and Natural Gas announced a purchase price for biodiesel at Rs. 25/litre effective January 2006, stating that “*Only those biodiesel manufacturers who get their samples approved and certified by the oil companies and get registered as authorized suppliers will be eligible for assured purchase of product*.” (The Hindu, 14/10/2005). The Indian Oil Corporation envisages using the purchased biodiesel as a 20% blend for diesel for transportation purposes. The price fixed for biodiesel (Rs. 25/litre in 2006) includes the cost incurred for purchase of raw materials (oilseeds, alcohol and lye), for production, for testing and for transportation to the purchase centre (which for Odisha is located over 300 km away from the CTxGreEn’s VLB project sites, in the neighboring State of Andhra Pradesh).

The issue of waiving the excise duty has been discussed by CTxGreEn with the State bureaucracy for the last three years, but without success. A study was conducted with the help of the Enviro Legal Defence Firm to understand the legal feasibility of Village-Level-Biodiesel production. A clear case has been made on behalf of producing biodiesel for productive livelihoods and subsistence activities over transportation fuel. The argument has also been made that alcohol used for productive livelihood activities should not be taxed in the same manner as alcohol used to prepare beverages and spirits. Moreover, alcohol is a raw material but biodiesel as a finished product does not contain alcohol. The study recommends that “there are two possibilities that can be applied to advantage to facilitate rural biodiesel initiatives: (1) Exceptions provided under the Medicinal and Toiletries

Preparations (Excise Duties) Act and (2) Exclusive Privilege Clause to obtain exemption on duties." (Upadhyay, 2005)[5]

A case has also been made under the Panchayats Extension to Scheduled Areas, PESA act (MPR, 1996), where there are special privileges to Schedule tribes (indigenous communities) in Scheduled Areas (Reservations). Under PESA provisions each person is allowed to brew between 7-18 kg liquor from rice or other cereals for bona fide consumption but not for sale. In Scheduled Areas, prior approval and permission for manufacture or sale of any intoxicant is decentralized and provided by the *Gram Panchayat* (Village Government) in concurrence with the Village Administrative bodies, usually at the level of the Ward (a conglomeration of villages) (Upadhyay, 2005).

Similar rules apply for the procurement and collection of forest produce, which has now been released from the State monopoly and is within the purview of the *Gram Panchayat*. Under the Joint Forest Management, the Village Forest Protection Council (called *Van Suraksha Samiti*, VSS) and the Forest Development Agency (a State agency) have a shared stake in the village forests. However, the *Gram Sabha* (village council) and the VSS together can regulate procurement and collection of forest produce. The constitutional role of the VSS has thus been legitimized through the *panchayat* legislation enacted under PESA (5, 2006).

It appears therefore that there is a policy climate conducive to the promotion of biodiesel as an alternative fuel. However, biodiesel and biofuel are mostly being seen as alternatives to diesel for transportation. Governments are promoting them with the main aim of import substitution and insurance against rising fossil fuel prices. Even in Brazil, where the distribution of bioethanol is well established, experiences in the promotion of a micro distillery project indicate that policies are focused on transportation and do not include household uses of bioethanol (Practical Action Consulting, 2008). Livelihood initiatives that create local self reliance, and can potentially achieve development without increased emissions, are being ignored in the policy-making arena. This is the case, not only in India, but all over the world.

How to best leverage existing policies to promote village-level production-and use in catalyzing livelihoods is the question to be addressed.[6]

Conclusion

Stakeholder consultations were held with senior bureaucrats in the Government of Odisha early in 2009 as it became clear that State policies were completely missing the VLB technology's potential for development. The meetings highlighted the need for development of partnerships to promote four key learning activities for catalyzing livelihoods based on the Village Level Biodiesel. These were:

- Curriculum development and technical training of village level entrepreneurs
- Enabling *Panchayati Raj Institutions* in local decision making for access and use of forest produce
- Feasibility assessments for scaling up and scaling out of the pilot village level biodiesel initiative
- Farmer's workshop to enhance agricultural productivity through the use of oil cake and biodiesel fuelled agro-services

The scaling up activity for the VLB technology in Odisha is currently being developed in partnership with academic institutions, entrepreneurship development Institutes and advocacy platforms consisting of grassroot NGOs. The spiral of replication of the VLB has been a very slow and incremental process. The focus away from subsistence activities to economic activities that reinforce local livelihood systems has made the innovation even

[5] Upadhyay, 2005; CTxGreEn & ELDF, 2007. Policy Imperative #1: Excise exemptions for manufacture of biodiesel including exemptions for scheduled areas. Also in CTxGreEn, 2007

[6] Inputs were given when CTxGreEn attended the meeting "Discussion of the Draft Biodiesel Policy" 05 Feb 2007, Bhubaneswar, Odisha, India, organized by the Odisha Renewable Energy Development Agency. The most important principle of local production for local use was left out when the policy was finally drafted.

more complex (Figure 6). While there has been a strong emphasis by CTxGreEn *w.r.t.* technological systems, articulation of needs by the communities and the role of meso level policies and local level institutions, more work is needed in enabling these grassroot organizations to gain access and control over local resources so as to obtain the full potential of the VLB (Figure 6). Local capacity building activity is a pre-requisite for anchoring the VLB technology in the community.

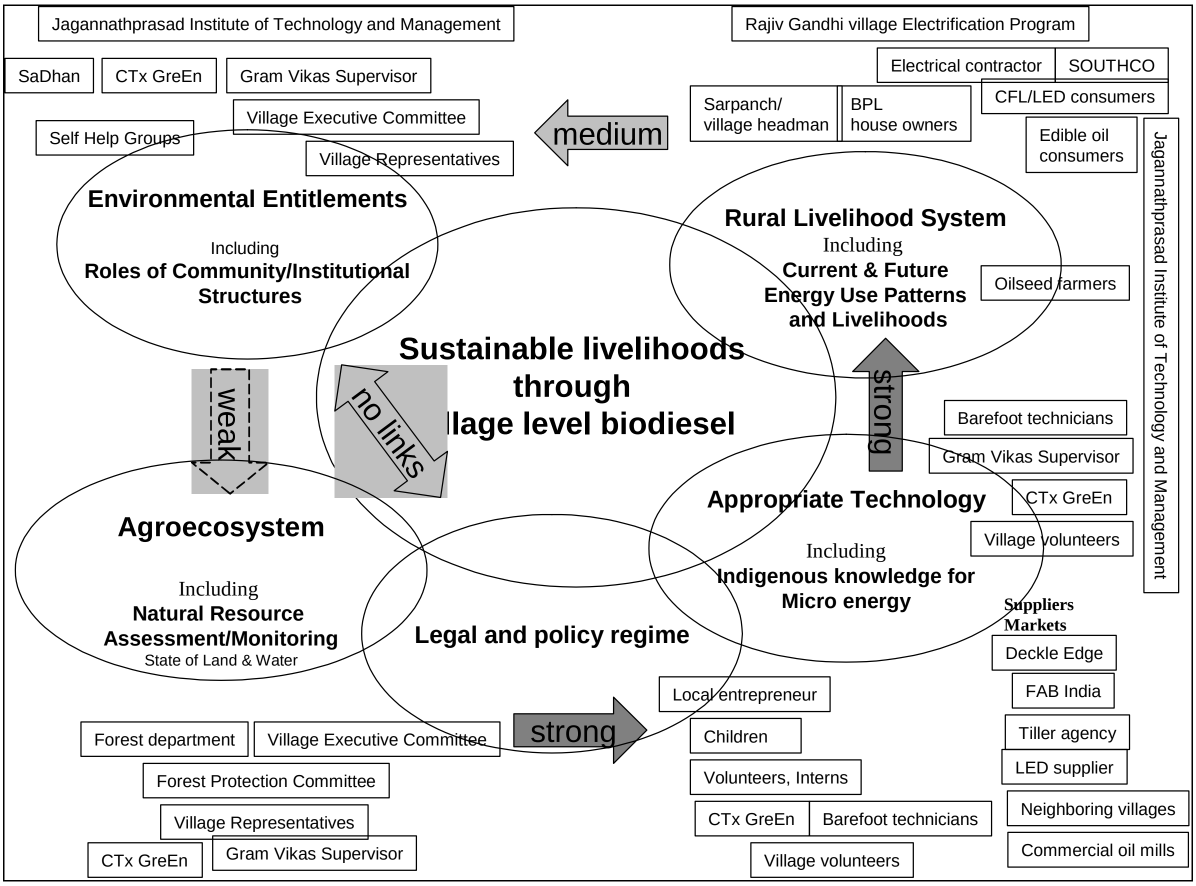

Figure 6: Interaction between the five components of the Village Level Biodiesel Technology (text within block arrows indicate the level of linkage currently established by the VLB)

It can be argued that the transitions of the VLB technology, which included reordering of the technology pathway and the repositioning of institutions of interest for its promotion is an experiment in sustainable transformations that has the potential to promote an alternative cleaner, greener growth model (Berkhout *et.al.,* 2010). It may be worthwhile to analyze the experiment using insights from literature on Strategic Niche Management, SNM (Veerbon, *et.al*., 2010, Berkhout *et.al.,* 2010) to understand how to firmly anchor and replicate the VLB technology and promote it as an alternative sustainable transition pathway – one that balances development and environmental agendas.

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