ABSTRACT
A community-based model of land management is proposed for pre-emptive action to reduce the risk of wildfires in small communities situated in forested areas. This proposed approach transfers the responsibility of wildland-urban interface administration to the local community, giving them control in reducing their risks of property damage. A combination of local labour clearing and community bioenergy power generation mitigates the cost of forest treatment, reduces the local cost of energy and revitalizes the community. The proposed solution achieves sustainable land management practices, sustainable ecology and sustainable energy production, and provides enhanced cost-benefits to the community. This study develops a viable method that is based on the installation of an appropriately sized combined heat and power system within a remote off-grid community by way of example.

Keywords: bioenergy, wildfires, CHP, mechanical treatment, sustainable communities

INTRODUCTION
Natural fire cycles have been artificially altered by forest practices and land management over the last few decades. Trends are showing increased fire size and severity over the last 20 years, resulting in increasing property damage (USDA, 2003a). A large quantity of hazardous biomass has been allowed to accumulate in forested lands. Recent experience of uncontrolled wildfires in British Columbia, Oregon and California overrunning communities has expanded public awareness of this hazard. Communities within forested areas are reviewing their exposure to wildfire risks and looking to develop proactive plans. Many small unincorporated districts lack the human resources to effectively produce these forest land management plans. Moreover, smaller communities are at greater risk of wildfire considering their greater encroachment into the forests, resulting in limited access and reduced insurance coverage. It is imperative that pre-emptive wildfire land management strategies consider the needs of these smaller and more remote communities.

LAND MANAGEMENT
There are three broad approaches to land management for wildfire control. Ignoring the issue defaults to the current reactive wildfire suppression with little or no pre-emptive control. This approach has been followed extensively and has resulted in the accumulation of a large quantity of forest fuel loading. The current acreage burnt each year by forest fires has decreased by more than 91% compared to 1870 conditions (Laverty and Williams, 2000). The problem is further compounded by issues related to drought, beetle-infestation, overstock of small trees, water stressed forests, and strict tree cutting policies in many communities. The second approach is for prescribed burns in which, under selected times and locations, intentional fires destroy the forest fuels to leave the woodland less susceptible to unplanned, uncontrolled wildfires. This practice is subject to weather conditions and smoke regulation. The third approach is mechanical treatment in which low lying biomass is harvested to reduce ladder fuels, along with a planned removal of selected larger trees to reduce crown fire spreading.

The reactive approach is rapidly being recognized as no longer acceptable. Ladder fuels and closely spaced trees allow fires to develop and expand beyond the capability of effective fire fighting. In the interface zones between forests and communities, those areas where homes
are constructed within the edges of the forest, the results of such fires are devastating. The prescribed fire approach is a pre-emptive method to reduce the fuel loading in the forest. However, prescribed burns cannot be implemented when there are high fuel loadings, short windows of suitable climate conditions, risk of escaped fire in the wildland-urban interface or where air quality concerns exist (USDA2003b).

The prescribed fire approach is an option with limited application in wildland-urban interface zones. In this case, mechanical treatment of forests is the only option. This approach consists of harvesting the underbrush, low level biomass, dead and dying trees as well as some forest thinning. Material removed in this manner must be consumed elsewhere as land filling would just shift the problem. Mechanical treatment of forest lands offers the potential of productive use of bio-feedstocks collected. However most of the biomass has no merchantable value and long-distance transportation generally precludes economic benefit from the valued material.

It is estimated that 20,000 communities are at-risk in the USA, that support for planned forest management is increasing, and that most of these communities have no local market for small diameter trees (Iversen and Demark, 20005). Furthermore, it is important to remove both ladder fuel and thinning of large trees to reduce crown fire spread (Keys and O’Hara, 2002) which precludes removing only merchantable trees. Fuel treatment programs need to remove large quantities of small trees; if left in the forest, these become ladder fuel, further increasing wildfire risk (USDA, 2003b).

**AT-RISK SMALL COMMUNITIES**

The fundamental risk to communities is due to the interface zones between the community and the forest. Attention is generally given to larger communities with this described profile. However the risk is as great or greater for smaller communities. It is the smaller communities that lack professional fire-fighting equipment and training, are more integrated with the forest, with limited access or routes of escape, are less protected financially and less organized to address the issue. As smaller communities are represented by fewer people, they have less capability to have their concerns and needs heard.

For large and small communities alike, the interface lands are an unresolved area of responsibility. These lands are often outside the tenures of the forest companies so land management is not a company issue. However they are also outside municipal boundaries for large communities and there are no municipal boundaries for unincorporated small communities. Thus these lands can default to government control and responsibility. Smaller communities are less able to input the necessary planning, contribute effectively to costs or even implement larger scale solutions. Small communities need a simple cost-effective solution that can be readily adapted to their specific needs.

**LAND MANAGEMENT COSTS**

A major concern of land management for wildfire control is the cost of proactive programs. The reactive approach required the least up front investment but the greatest uncertainty in budgetary planning with potential expenditure being unbounded. A single uncontrolled wildfire that encroaches onto a populated area can cost many times more than any of the pre-emptive programs. If the forest fuel loading is high, then few reactive strategies can be relied upon to ensure that a disaster does not ensue. The costs of fire fighting, property destruction, employment losses, insurance claims and legal implications can exceed $1 billion in a single season in the USA but this is a statistical result and not a comparative per acre cost. It is not
possible to make a direct comparison to costs of pre-emptive programs for fire control on an annual basis. Prescribed burns are the least-cost pre-emptive strategy with an estimated cost of $130 to $1,000 Cdn per hectare (USDA, 2003b) but this method has restricted application. Prescribed burns have no secondary benefits available. A related approach is to cut, pile and slash burn the forest fuels. This uses a combination of mechanical clearing with a more controlled in-forest burn. It has similar health limitations as the prescribed burning approach and is estimated to cost more: $370 to $2,800 (Cdn) per hectare (USDA, 2003b).

Mechanical clearing and removal is a more costly pre-emptive strategy but it can offer secondary benefits if the available biomass is used for economic purposes. In addition to reduction of forest fuels, the recovery of whitewood in chip form produces a valued commodity, albeit mitigated by transport costs. However, there is no quality requirement for biomass that is used as fuel for heat recovery combustion. The costs of mechanical clearing are typically defined by weight of biomass collected rather than forest area treated. Typical costs to clear and remove biomass from the forest are $50 - $70 (Cdn) per BDT with forest fuel load estimated at 25 to 35 BDT per hectare (USDA, 2003b). Alliteratively the Rural Technology Initiatives show that average mechanical treatment costs are $360 to $600 Cnd per acre which need to be balanced against non-monetized benefits which are estimated at $1,550 to $2,600 Cnd per acre (Mason, 2003).

**BIOENERGY AND COMMUNITY INVOLVEMENT**

Proposed uses of wood residues from mechanical treatment including CHP, co-firing, wood pellets, bio-oil and methane production (Polagye, 2006) for large scale systems where the wood residues are transported to a large-scale facility. Except for co-firing, these proposed large scale scenarios have been shown not to be economical (Polagye, 2006). Instead we propose to use small scale distributed bioenergy systems similar to those that have been modelled using technologies adapted for the 250 to 5,000 kWe range for forest residues and bugwood applications (Tampier et al., 2006 and Tampier et al., 2006). These small communities cannot rely on the availability of large-scale facilities to use the relatively small amount of biomass they collect from mechanical treatment.

It is particularly problematic for communities of less than 200 households to effectively plan and implement a wildfire control strategy. Many of these communities are highly integrated in forested lands and have limited access. This implies that they are more threatened by wildfire both in terms of avoiding property damage and in terms of escape. However, these communities are likely less able to fund a planned mechanical treatment of the forest.

Similarly, it is unrealistic for outside services to attempt to evaluate the needs of every small community with respect to forest management. It would be prohibitively expensive, time consuming and demanding of limited knowledge resources to perform a site-specific evaluation of every small community. It is not possible to develop a multitude of individual land management plans. What is needed is an approach that can be adapted readily to individual areas without significant input from outside experts. With the availability of such a plan, the remaining deterrent will be the initial cost of implementation, training and on-going support.

**COMMUNITY ENERGY COSTS**

Mechanical forest treatment would be an attractive option if the cost structure were made more favorable through recovery of some revenue and community benefits. If collected biomass was used to generate power and heat for the community to displace existing energy
expenditures then the recovery of value would mitigate part of the forest treatment cost. This requires an appropriate system that can effectively convert the available biomass to useful forms of energy.

Electrical power in small communities is often provided by diesel generation. This is very high-priced power valued between 20¢ and can exceed $1.00 per kWhr. For instance, if diesel fuel costs $2.50 per litre in the community, the direct conversion to electricity equates to 50¢ per kWhr and that excludes operating, maintenance and capital cost recovery. In addition, building heat in small communities is often partially provided by heating oil. The consumer retail heating oil price often exceeds the bulk diesel fuel price in the community. It is not unusual for annual heating costs to exceed electricity expenditures in remote areas. It should be noted that although electrical power costs are often highly subsidized, most often heating oil does not receive such subsidies. The community must generally pay full price for their imported heating oil and its transportation to site.

A COMMUNITY-BASED MODEL
The forest fuel load is generally on a seven year cycle (FERIC, 2003). If the biomass that serves to fuel a wildfire is cleared, it will replenish itself in about seven years. Any forest treatment plan must address this continuing need. A land management plan would place the primary responsibility for management and implementation of forest treatment with the local community. It is not useful to remove forest fuels without having a plan for its destruction or use. This proposed concept includes an on-going forest fuel removal program managed by the community, using community workers and coupled with a biomass power generating system within the community. The cost of labour is minimized because highly qualified outside labour is not needed. Furthermore, forest treatment costs are mitigated by the value of power generated and sold within the community. Numerous other benefits would also accrue to the community. Transportation costs are significantly reduced.

As an example, a community of 100 households, community buildings and some businesses may be served by a biomass power generating system sized for a maximum production of 250 kW of electrical power. Such a system would require a maximum of 0.5 BDT of biomass residues per hour. Average usage could be expected at less than 75% generation capacity. With a forest fuel loading of 25 BDT per hectare, a seven year usage cycle would reach a 2.75 km radius around a community having an area of 0.5 km². Forest treatment work is mainly the harvesting of underbrush and small trees. This work is largely comparable to landscaping work rather than forest logging. Workers need training and direction but minimal qualification. The equipment required for such work would include small chainsaws, landscape chippers, transport ATV and chip trailers. The work would entail clearing less than one hectare daily in an expanding radius around the community. Clearing by individuals around their personal property would be accepted as further fuel and the community could choose to accept other municipal waste or construction material. A corporation, owned by the community, would oversee and manage the procedures and system. Collecting biomass at a rate faster than it is consumed and using short-term storage would allow a 5 day work week and possibly even a seasonal collection period.

Electrical power generated by the biomass system would be supplied through the existing local distribution system and would displace electrical power being generated by other means like diesel. Thermal heat could also be made available to the community as high temperature water suitable for district heat. It is anticipated that only a portion of the available heat will be utilized initially for central buildings such as meeting halls, community offices and schools.
The infrastructure required to carry this heat to private homes would be installed progressively. The upgrades to utilize this heat would be financed by the savings realized by displacing heating oil. The heating oil for central buildings displaced by thermal heat from the biomass system represents considerable financial value to the community. The upgrades to utilize this heat in individual homes represent future financial benefit.

**BIOMASS SYSTEM REQUIREMENTS**

The primary requirement of the biomass power generating system is low capital cost in a small generating size. Smaller bioenergy systems are significantly more expensive per kW and usually uneconomical. Newer small-scale systems using the Organic Rankin Cycle (ORC) and the Entropic Rankin Cycle (ERC) offer combined heat and power from biomass (Bibeau et al., 2005) with commercial units estimated to cost $3,000 per kW. For remote installations it is imperative that a power generating system operate with minimal operator qualification and unattended. Steam-based bioenergy systems have a distinct disadvantage as due to their boiler they require highly trained on-site operators with registered qualifications. The labour cost of such operators becomes prohibitive for small-size systems. Moreover, a remote community may have difficulty hiring and keeping such specialized labour. The ORC and ERC bioenergy CHP systems operate similar to steam but do not use a traditional boiler and thus dose not have the requirement for a highly-qualified operator. Furthermore these bioenergy systems can be automated and thus operated reliably in remote locations.

**Table 1: Community Revenue Schedule**

<table>
<thead>
<tr>
<th>Size:</th>
<th>100 households</th>
<th>school, store, hall, etc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area: interface lands</td>
<td>½ km² town centre</td>
<td>2 ¾ km forest radius</td>
</tr>
<tr>
<td>Power:</td>
<td>250 kW ERC</td>
<td>180 kW average usage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>250 kWe peak</td>
</tr>
<tr>
<td>Capital Cost:</td>
<td>$50 / BDT</td>
<td>5 year payback</td>
</tr>
<tr>
<td>Operating Cost:</td>
<td>$50 / BDT</td>
<td>expended locally</td>
</tr>
<tr>
<td>Biomass Clearing:</td>
<td>134 hectares / year</td>
<td>7 year cycle</td>
</tr>
<tr>
<td></td>
<td>3,350 BDT / year</td>
<td></td>
</tr>
<tr>
<td>Electricity:</td>
<td>$28.85 / BDT</td>
<td>town centre using 10% of</td>
</tr>
<tr>
<td>(displaced @ 5.77¢/kWhr;</td>
<td>$61.25 / BDT</td>
<td>heat available (6,300 litres</td>
</tr>
<tr>
<td>subsidized @ 12.25 ¢/kWhr)</td>
<td></td>
<td>per year)</td>
</tr>
<tr>
<td>Heating Oil:</td>
<td>$10 / BDT</td>
<td></td>
</tr>
<tr>
<td>(displaced @ 50¢ /litre)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**REVENUE MODEL**

The specific revenue model applicable to any given site will vary due to local differences. It is clear that there is significant expense if we choose to address the hazard of wildfires in a proactive manner. However, remaining reactive to forest fires can lead to an even greater cost from significant property damage. Table 1 shows the revenue streams for a small community. This example has been designed to break even and cover the costs of mechanical treatment surrounding the community. Current subsidized electricity rates are, in many cases, greater than indicated and different jurisdictions support subsidies in different ways. Heating oil costs may be substantially different in many locations. In addition, a community could almost double its income revenue with full advantage taken of available heat. No carbon credit has been allotted to the environmental benefit of reducing net greenhouse gas emissions.
CONCLUSION
A community-based model is proposed in which a forest mechanical treatment is combined with a biomass power generating system sized to suit a small community. Multiple units could be distributed in larger communities. The system could be scaled appropriately or applied to special local forest needs such as forest thinning. Forest treatment would be done by community workers with benefits of the program remaining in the community. Power and heat would be generated and used by the community to displace energy dollars leaving the region. The wildland-urban interface zone would be cleared over a seven year cycle to a radius of 2.75 km around a 100 household community to offer a reduced risk of wildfire. Most importantly the responsibility for forest fire mitigation, the power generating system and the associated benefits would be owned, managed and accrued by the community. Decisions to reduce risks would not be external to the community. The proposed system is sustainable ecologically and uses sustainable renewable biomass to generate heat and power. The goal of this community plan is to reduce fire hazards, decrease property damage, improve public safety, promote forest health, and achieve sustainable unsubsidized cost-benefits. Avoidance of treatment may lead to increased fire suppression costs, property damage and environmental damage.

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