



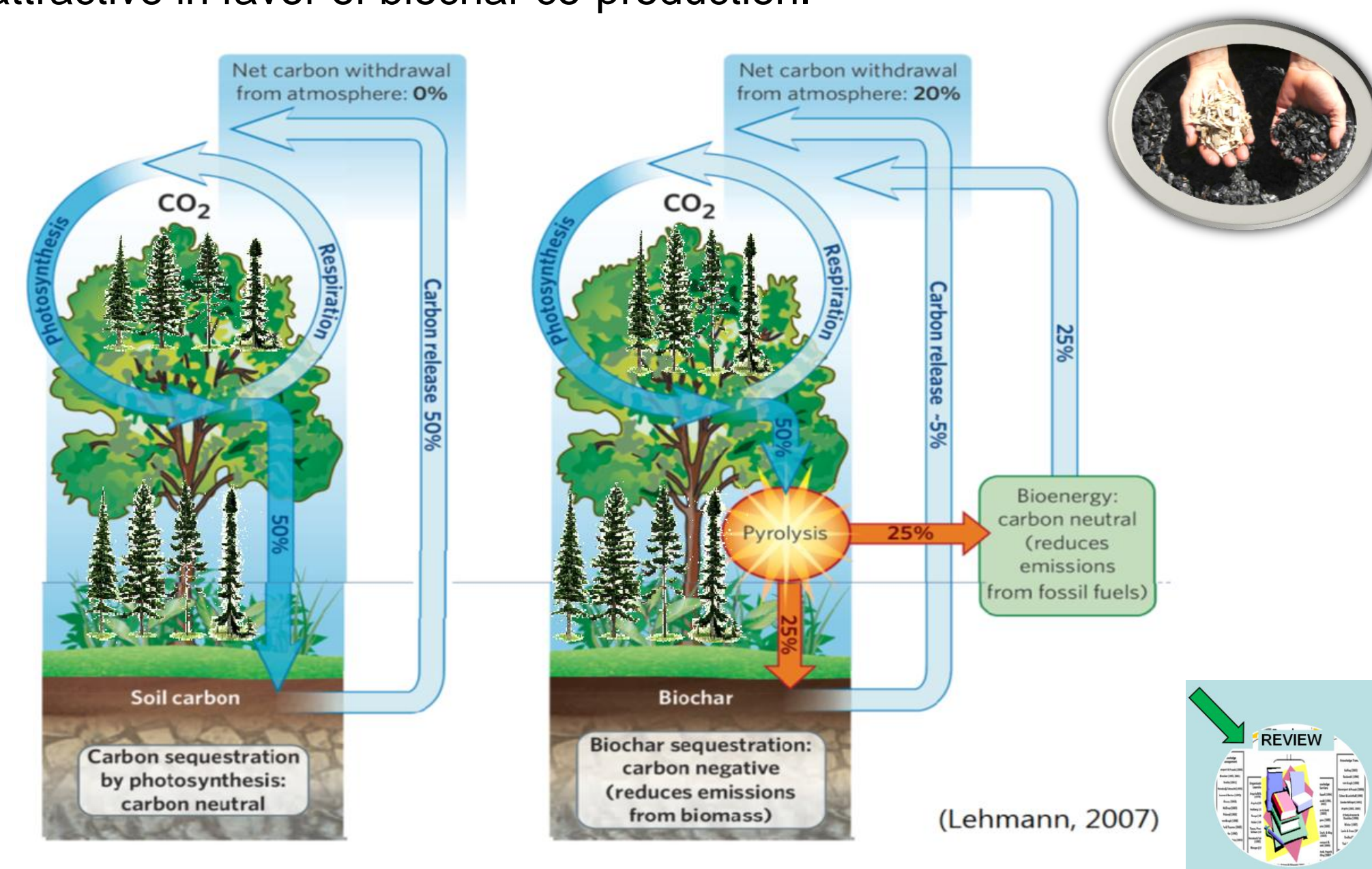
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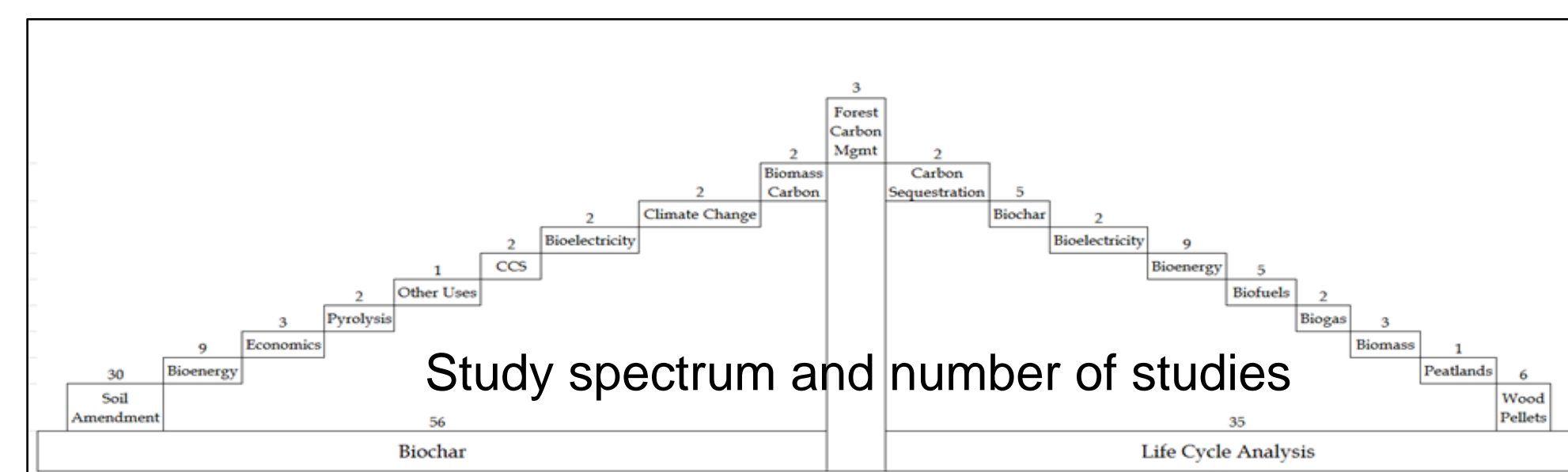
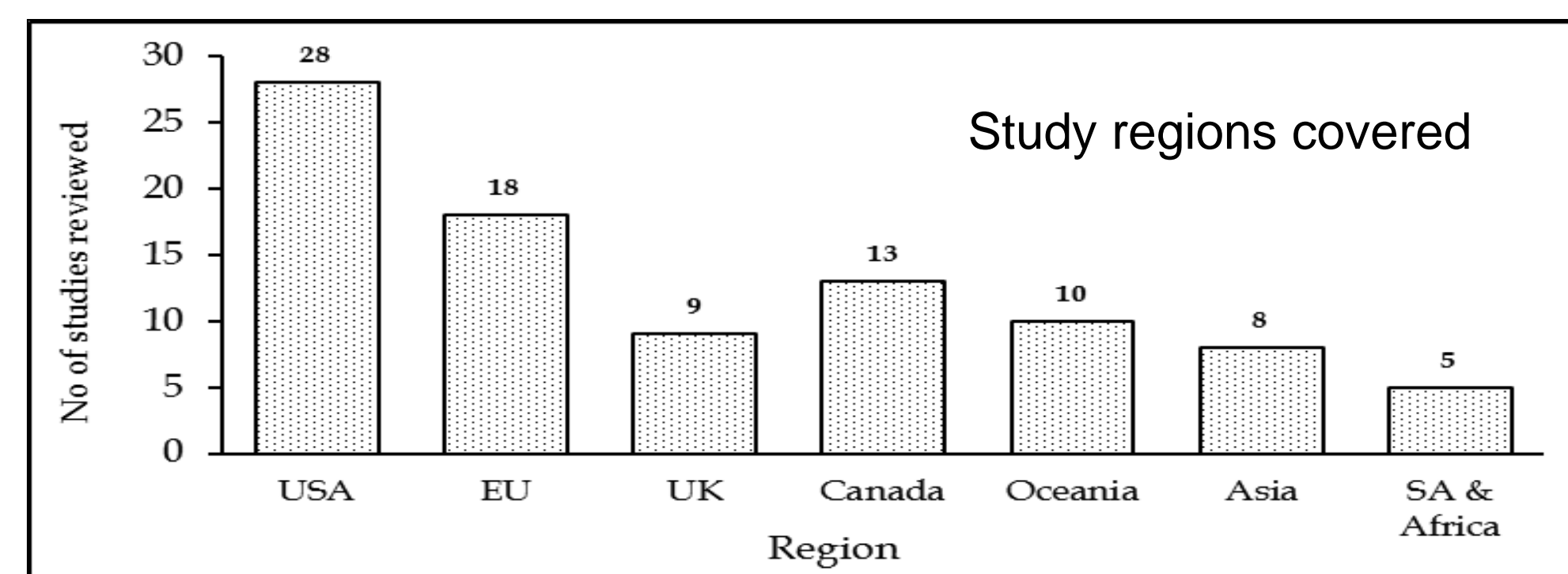
Climate change and related environmental disasters are continuously posing threats to sustainable livelihood of forest and natural resources dependent communities in northern Ontario. Current efforts in changing forest tenure systems and involvement of local communities in forest resources management can create some opportunities to mitigate and adapt from adverse effects by creating carbon friendly communities. Reduction of greenhouse gas (GHG) emissions by replacing fossil fuels with biomass derived energy was identified by the United Nation's intergovernmental panel on climate change (IPCC) as one of four forest sector climate change mitigation options. Vast availability of woody biomass in the region and growing concerns in biomass energy coincides with the Ontario government's decision to eliminate coal-fired energy generation by the end of 2014. Bioenergy is considered as the carbon neutral solution of the current environmental crisis. Biochar is a by-product of bioenergy, which can sequester carbon for a longer time if applied in the soil and it is claimed to be carbon negative in the life cycle. Fossil fuel related emissions are often blamed to be one of the biggest contributors of the current environmental greenhouse gas mix and subsequent global warming. Fossil fuel makes a significant proportion in the current power supply mix in Ontario. There are a lot of other bioenergy initiatives in different scales including community pellet initiatives and combined heat and power (CHP) plants. The use of biomass feedstock for producing biochar and bioenergy not only has the potential to address the environmental problems related to air pollution and climate change, but also ensures job and energy security for local communities. Recently established local forest management corporations (LFMCs) in Ontario can incorporate biochar-based bioenergy in their forest and carbon management plans.

This poster is a part of a big project on modeling of the life cycle environmental impact of biochar-based bioenergy production and conducting its economic analysis in northern Ontario. Here we present a brief synopsis of results on review of the status of peer reviewed and published papers (i) to analyze the availability and sustainable supply of woody biomass for future biochar-based bioenergy system; (ii) to compare the efficient use of woody biomass for bioenergy production systems using biochar with conventional methods; (iii) to study environmental impacts of biochar production, its land application and carbon management potential; and (iv) to identify the research needs and potential environmental impact assessment methods for woody biomass utilization for bioenergy production in northwestern Ontario in a sustainable basis.

Biochar is a stable, recalcitrant organic carbon compound co-produced from the heating of biomass under low or zero oxygen condition (Pyrolysis) along with bioenergy. Bioenergy is carbon neutral and biochar is considered as carbon negative if managed properly in the long run. The co-production of biochar from a portion of the biomass feedstock may reduce the total amount of bioenergy that is produced by the technology, but even at today's energy and fertilizer prices, the net gain in soil productivity is worth more than the value of the energy that would otherwise have been derived from the bioenergy. As the cost of carbon emissions rises and the value of CO₂ extraction from the atmosphere is also considered, the balance becomes overwhelmingly attractive in favor of biochar co-production.



Selected papers from ISI web of science database with the combinations of keywords like "biochar", "life cycle assessment", "bioenergy", "soil amendment", and "northwestern Ontario" and related other grey literatures were reviewed. Similar keyword search combinations were used to find more published articles from Google Scholar and Proquest. The extent of papers reviewed is more or less universal with most are published in the USA. However, the proportion of reviewed papers for Canada was 1/7 of which only 3 papers were directly related to northwestern Ontario.



Woody biomass availability (Million tonnes per year) in northern Ontario

Source	Quantity available per year	Reference	Remarks
Forest harvest residue and underutilized tree species	7.9 million green tonnes	Alam et al. (2012)	Northwestern Ontario
Woody and agri based biomass	34 million dry tonnes	(Hacatoglu et al. 2011)	Includes Canadian side of Great lakes region
Harvest residue, sawmill residue and underutilized hardwoods	2.3 million dry tonnes	Kennedy et al. (2011)	Parts of Northeastern Ontario
Traditionally unmerchantable, unused and available trees	7.6 to 7.9 million green tonnes	MNR (2011)	All over Ontario but harvest and Saw mill residue not included
Harvest residue and sawmill residue and residual trees	3.8 million dry tonnes	Wood and Layzell (2003)	Factored @ 5% for NW Ontario from 77 million dry tonnes for all Canada

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graph TD; A[Cover crop management] --> B[Physical impacts]; A --> C[Chemical impacts]; A --> D[Biological impacts]; B --> E[Plant/Crop/Pasture system]; C --> E; D --> E; E --> F[Increase soil water storage, access through enhanced aggregation]; E --> G[Enhance input efficiency: Fuel, fertiliser, water]; E --> H[Increase yield, plant growth]; E --> I[Increase soil carbon sequestration]; E --> J[Enhance disease resilience];
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The flowchart illustrates the effects of cover crop management on soil health and the plant/crop/pasture system. It starts with a central box labeled "Cover crop management" at the top. Three arrows point down from this box to three separate boxes: "Physical impacts", "Chemical impacts", and "Biological impacts". Each of these three boxes contains a list of effects. Arrows from each of these three boxes point down to a single box labeled "Plant/Crop/Pasture system". Finally, an arrow points down from this box to a large box at the bottom containing a list of system-level benefits.

Cover crop management

- **Physical impacts**
 - Enhance aggregate stability
 - Reduce tensile strength
 - Increase hydraulic conductivity
 - Increase soil porosity
 - Increase water holding capacity
- **Chemical impacts**
 - Ameliorate pH
 - Increase CEC and nutrient retention
 - Increase long-term C pool
 - Increase nutrient supply
 - Enhance metal and organics sorption
- **Biological impacts**
 - Provide microbial habitat
 - Alter microbial functions, size, structure, and diversity
 - Enhance mycorrhizae-plant associations
 - Promote biological nitrogen fixation by legumes

Plant/Crop/Pasture system

- Increase soil water storage, access through enhanced aggregation
- Enhance input efficiency: Fuel, fertiliser, water
- Increase yield, plant growth
- Increase soil carbon sequestration
- Enhance disease resilience

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graph TD
    Biomass["Biomass:  
Purpose grown crops  
Plant residues  
Animal manures  
Biosolids  
Other organic wastes"]
    Pyrolysis["Pyrolysis"]
    Biochar["Biochar"]
    SoilApp["Soil application"]
    Bioenergy["Bioenergy:  
gas, oil"]
    Fuel["Fuel"]
    PlantSoil["Plant-soil system"]
    ClimateAdapt["Climate change adaptation"]
    ClimateMitig["Climate change mitigation"]

    Biomass --> Pyrolysis
    Pyrolysis --> Biochar
    Pyrolysis --> Bioenergy
    Biochar --> SoilApp
    Biochar --> Fuel
    SoilApp --> PlantSoil
    SoilApp --> ClimateAdapt
    SoilApp --> ClimateMitig
    Fuel --> ClimateMitig
    Bioenergy --> ClimateMitig

    PlantSoil -- "Feedback loop (more biomass)" --> Biomass
    ClimateMitig -- "Feedback loop (greater C input)" --> Biomass
    ClimateMitig -- "Reduced fossil fuel emissions" --> Bioenergy
  
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The flowchart illustrates the Biochar Cycle. It begins with **Biomass** (Purpose grown crops, Plant residues, Animal manures, Biosolids, Other organic wastes), which undergoes **Pyrolysis** to produce **Biochar** and **Bioenergy: gas, oil**. **Biochar** is then used for **Soil application** or as **Fuel**. **Soil application** leads to the **Plant-soil system**, **Climate change adaptation**, and **Climate change mitigation**. **Fuel** and **Bioenergy** contribute to **Climate change mitigation**. The **Plant-soil system** and **Climate change mitigation** both provide a **Feedback loop (more biomass)** back to the initial biomass source. Additionally, **Climate change mitigation** results in **Reduced fossil fuel emissions**, which is linked to the **Bioenergy** output.

- ✓ **Renewable** – Sustainably-managed sources of biomass can provide fuel indefinitely.
- ✓ **Readily available** – A significant amount of biomass fuel is available in most regions of North America in the form of agricultural crops and waste, forestry, and municipal waste.
- ✓ **Dispatchable** – A biomass-fired generation plant can increase or decrease electricity production in response to demand. This is an important factor in incorporating a variety of energy sources in the overall system.
- ✓ **Part of the natural carbon cycle** – Drawing energy from biomass utilizes the carbon within the natural carbon cycle. Biomass draws carbon from the atmosphere during its growth cycle and releases carbon when it is combusted.
- ✓ **Local resource** – Biomass energy is typically fuelled by local sources of biomass, creating local economic development opportunities.

(Source: OPG, 2011)

Emissions comparison based on 100% wood pellet trials at Atikokan GS in July 2008:		
	Lignite Coal	Biomass Wood-Pellet
SO ₂ emissions	4.2 kg/MWh	Negligible
NO _x emissions	1.5 kg/MWh	0.6 kg/MWh

Review shows very promising potential environmental benefits of biochar-based bioenergy system in general. Most of the studies were limited to non-boreal region and the broader applicability of these findings needs area specific study. Long term biochar trial plots in the boreal region need to be established and life cycle environmental and cost assessment of the overall system need to be conducted so that communities can manage their resources and become carbon friendly.