Urban Forest Biomass to Biochar Playbook

CNCA Biochar-Urban Forest Strategy

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Additional information on the environmental and carbon impact potential of biochar can be found at the Biochar-Urban Forestry Strategy resource library, hosted by Nature-Based Climate Solutions.

Introduction

This playbook aims to provide guidance to municipalities looking to utilize urban forest biomass in the production of biochar. The following framework and recommendations were developed based on biochar research and case studies across four peer cities: Boulder, Helsinki, Minneapolis, and Stockholm. This international collaboration was coordinated by Nature-Based Climate Solutions (NCS) and supported by the Carbon Neutral Cities Alliance (CNCA).

Additional resources – including individual strategies for each of the four participant cities, a benefits analysis of biochar impact, and a guidance for selection and proper application of specific biochars – can be found on the Nature Based Climate Solutions website.

The Biochar Opportunity

Biochar is a carbon-rich solid resulting from the thermal decomposition of organic matter in a low or no-oxygen environment. Biochar can be produced from a variety of feedstocks, including wastewater sludge, green waste, manure, and food scraps. Both input feedstock and production technology play a significant role in affecting the quality and properties of resulting biochar. This study focuses on the creation of biochar from woody biomass resulting from urban forest management activities (ie. tree removals and maintenance work). Generation of biochar from urban forest biomass presents an opportunity to drive two primary forms of environmental impact:

1. **Carbon storage through utilization of woody biomass.** Within the United States alone, urban forests are estimated to store 834 million metric tons (MT) of carbon across 1.67 billion MT of dry-weight tree biomass; furthermore, an estimated 2 to 7% of that woody biomass is expected to be lost each year due to tree mortality.[1] For municipalities looking to manage their wood waste stream, biochar production presents an opportunity to displace common disposal pathways – including chipping, decomposition, and burning – that quickly release stored carbon into the atmosphere. Instead, pyrolysis of biomass can sequester carbon in a stable charcoal and avoid the creation of greenhouse gasses.

   Among the four peer cities studied in this project, estimates of potential annual carbon impact from biomass utilization as biochar ranged from **400 to 2,053** metric tons of CO_2e reductions per year in Boulder, Colorado – a city just beginning to explore large-scale biochar application opportunities – to as much as **18,874 to 46,630** tons per year in Helsinki, Finland, where a variety of public infrastructure and resident uses of biochar have already been implemented.

[1] Nowak, David J.; Greenfield, Eric J.; Ash, Ryan M. 2019. Annual biomass loss and potential value of urban tree waste in the United States. Urban Forestry & Urban Greening. https://doi.org/10.1016/j.ufug.2019.126469.

2. **Ecosystem benefits derived from local biochar application.** Biochar has been shown to improve vegetative growth and plant health,[2] increase soil water holding capacity[3] and filter salt and heavy metals in roadside applications.[4] As a result, increased availability and use of biochar offers a number of potential environmental benefits within forestry, agriculture, and stormwater management applications. By effectively utilizing biochar in urban forest plantings, city forestry staff, nonprofit partners, and residents may be able to significantly increase the growth of local canopies, while reducing certain types of disease-related mortality.[5]

Additional information on the environmental and carbon impact potential of biochar can be found in the "Biochar Benefits Analysis" document within in this project's resource library.

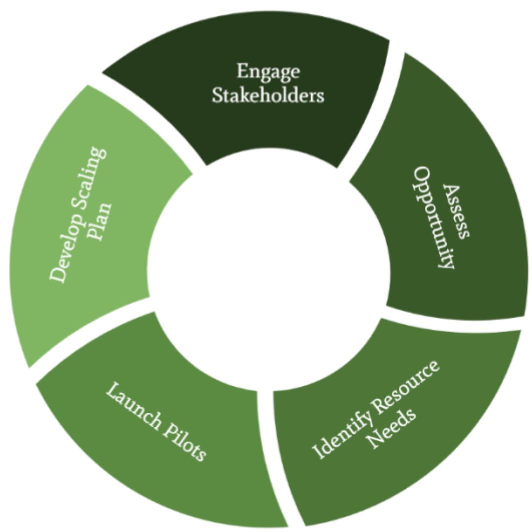
Strategy Development

The following section outlines key pillars to developing a place-based roadmap for biomass utilization as biochar:

Stakeholder Engagement

Successful implementation of a regional biomass to biochar production system requires engagement of key stakeholders, including:

- Government officials (city, county, state)
- Local arborists and tree care companies
- Existing biochar and biomass processors
- Biochar researchers & experts
- Potential biochar users
- Community groups



A critical first step is the identification of a **project champion** who can engage and coordinate participation among relevant community members. Initiatives in Boulder and Minneapolis began with the development of regional steering committees (led by the city's project lead) that provided guidance and feedback, along with

[2] Scharenbroch, B.C. et al. 2013. Journal of Environmental Quality 42 1372-1385 "Biochar and Biosolids Increase Tree Growth and Improve Soil Quality for Urban Landscapes"
[3] Omondi, M et al. 2016. Geoderma 274 28-34 "Quantification of biochar effects on soil hydrological properties using meta-analysis of literature data."
[4] Seguin, R. et al. 2018 Water Air Soil Pollution 229:84 1-15 "Remediating Montreal's Tree Pit Soil Applying an Ash Tree-Derived Biochar"
[5] Zwart, D.C. and Kim, S-H. 2012. Hort Science 47 1736-40 "Biochar Amendment Increases Resistance to Stem Lesions Caused by Phytophthora spp. in Tree Seedlings"

recommendations of interviewees and potential project partners. It is critical that existing players in tree care and management provide feedback on perceived opportunities and barriers to local biochar production and use, to help inform strategy development.

Opportunity Assessment

Understanding and quantifying the potential scale of a biomass-biochar system requires evaluation of the feedstock waste stream. Top-down tree inventory data and bottom-up survey responses from tree care companies are two possible methods for gauging the **volume** and **composition** of wood waste available for biochar production. Additionally, understanding the current flow of woody biomass from the urban forest (eg. to organic recycling facilities, landfill, or other disposal pathways) can help establish a baseline for evaluating net carbon impact potential from diversion of wood waste into a pyrolysis process.

The below table compares the estimated urban forest biomass generation / biochar production potential within the four cities participating in this project. It should be noted that estimates of available wood debris from urban trees will continue to fluctuate based on factors including ongoing efforts to scale local plantings and total forest biomass, as well as increasing severity and frequency of climate-related stress and weather events – causing surges in downed trees.

Table 1. Biochar Potential in 4 Case Study Cities

City	Population	Available urban tree biomass (MT annual)	Production Technology Assumption	Estimated biochar production potential (MT annual)
Boulder, USA	108,777	**9,041 tons** (estimated total)	community-scale TrollWorks system	**1,356 tons**
Helsinki, Finland	658,864	**8,500 tons** (estimated total)	Industrial pyrolysis system	**1,700 tons**
Minneapolis, USA	443,715	**4,481 tons** (City tree removals) **56,148 tons** (County wood waste)	2-line ARTi reactor	**1,120 tons** (city biomass) **14,037 tons** (county-wide)
Stockholm, Sweden	978,770	**3,800 tons** (current collection)	Pyreg	**290 tons**

Resource Identification

In order to move forward with pilot use, specific resource needs must be identified, including:

- **program ownership and structure**: will the government procure equipment to produce biochar in-house, develop a public-private partnership to contract out waste processing, or simply procure locally-sourced biochar from private operators?
- **production infrastructure**: technology or equipment needs, and site for woody biomass storage and processing. For additional information on technology selection, see "Urban Bioenergy-Biochar: An Opportunity Assessment for Municipalities."
- **offtake avenues**: identification of application areas and offtake partners to utilize resulting biochar.
- **budget**: key costs may include per ton biochar pricing (if procured from a private partner), equipment costs (if procured internally), and operating costs (eg. transportation, labor for application, etc.).

Launch Pilot Projects

Providing a proof-of-concept can help demonstrate biochar's impact potential and test feasibility prior to more significant investment in program development. Given the variability in biochar characteristics as well as application-specific impacts, evaluation of outcomes from local pilots is critical to accurately gauging local economic, environmental, and social impacts. For example, testing biochar's water conservation impacts in turf management could help make the case for more widespread adoption and application. Similarly, trialing roadside application of biochar as a means of pollutant remediation could help demonstrate to local and state agencies the utility of writing biochar into roadway management plans and design guidelines.

A number of cities are actively developing government-lead biochar pilots. One such project launched in Park City, Utah is exploring the incorporation of biochar as a surface dressing on aerated turf. For an example of a biochar pilot conducted by the City of Minneapolis, see "*Case Study: Hiawatha Ave,*" below.

Case Study: Hiawatha Avenue

A joint effort between Hennepin County and the City of Minneapolis, this stormwater infrastructure project took place in the fall of 2019 along State Highway 55 (Hiawatha Avenue). The four-lane divided highway connects downtown Minneapolis to the Minneapolis/St. Paul International Airport. The corridor is maintained by Hennepin County under an agreement with the Minnesota Department of Transportation (MNDOT).

Over time, the soil in Hiawatha Avenue's grass median had become compacted and overrun by weeds. The County received a grant to restore vegetation with a pollinator lawn mix, and replace dead trees along a four block stretch of the roadway.

Rather than rebuild the existing system, Hennepin County teamed up with the City of Minneapolis to construct a swale to improve rainwater infiltration.

Medians often present a harsh environment for vegetation, given their high exposure to road salt. To increase infiltration, reduce maintenance, and increase vegetative growth, the project team replaced the existing crowned, compacted soil with a compost/biochar mix.

Compost from the Shakopee Mdewakanton Sioux Community (SMSC) Organics Recycling Facility (ORF) was mixed with biochar supplied by the City of Minneapolis. A hardwood biochar (prepared by slow pyrolysis at 650^{o} C) was mixed at a ratio of 1-part biochar to 9-parts compost. A total of 15 cubic yards of biochar were used.

The City of Minneapolis Public Works removed soil from the median and shaped the swale. Biochar and compost were then mixed into the upper 6-inches of soil. County staff planted a pollinator mix and covered it with burlap. Hennepin County replaced 40 trees with a variety of bare-root stock, backfilled with a mix of soil and a 50-50 biochar/compost mix. The project aims to reduce mortality and increase vitality of the replacement trees.

Next steps will include measurement and evaluation of pollinator populations by the University of Minnesota. For now, the mix is well established and has successfully weathered two winter seasons.

Develop Scaling Plan

Large-scale application of biochar within urban landscapes presents an opportunity to create a significant and stable carbon sink. A "Carbon Lane" case study developed by Aalto University and the University of Helsinki found that the addition 20,000 - 30,000 cubic meters of biochar in new planting soils could remove a collective 18,000-28,000 tons of carbon emissions annual, an equivalent to roughly 0.7 to 1% of Helsinki's annual emissions or 3.5 to 5% of the city's total negative emissions goal.

In order to achieve sustained and scaled biomass utilization, it is critical to identify regional markets and applications for biochar. Common volume uses of biochar include urban forestry and turf management, agricultural use, and stormwater remediation. A sample of potential applications for wood-based biochar in Helsinki, Finland, is provided in the table below. Biochar volumes were converted to metric tons based on a conversion of .3 tons per cubic meter[6] and sequestered carbon dioxide equivalent was assumed to be 2x per ton of biochar use.[7]

Table 2. Biochar Application Potential in the City of Helsinki

Application Area	Use estimates	Biochar potential		Estimated Carbon Sink
		Minimum	Maximum	
Tree planting	1,000 trees/year (8m^3 - 25m^3 soil per tree, 10% biochar inclusion)	800 m^3 /year (240 tons)	2,500 m^3 /year (750 tons)	480-1500 tons CO_2e
Roof gardens & green walls	90,000 m^2 of green roofs (increasing 10% each year) 100mm thick soil layer, 30% biochar by vol.	270 m^3 /year (81 tons)	9,000 m^3 /year (2,700 tons)	162-5400 tons CO_2e
Sport fields	2,000,000 m^2 of sport fields with 10-15% maintenance rate; 0.4m thick soil layer; 5% biochar by vol.	4,000 m^3 /year (1,200 tons)	6,000m^3 /year (1,800 tons)	2,400-3,600 tons CO_2e
Soil fill /structural soil	200,000m^3 – 475,000m^3 park/ vegetated roadside / bioswale /gardens; 10% biochar by vol.	20,000 m^3 /year (6,000 tons)	47,500m^3 /year (14,250 tons)	12,000-28,500 tons CO_2e
Meadows & agricultural land	4,200,000 m^2 under City of Helsinki Administration; 300mm topsoil layer; 5-10% biochar by vol.; 10% annual maintenance rate	6,300m^3 /year (1,890 tons)	12,600m^3 /year (3,780 tons)	3,780-7,560 tons CO_2e
Stormwater filter	Stormwater retention basins, biofiltration systems, etc.; estimated 10 new basis per year; soil thickness 0.5m-1m; biochar 10% vol.	85m^3 /year (26 tons)	1,170m^3 /year (35 tons)	52-70 tons CO_2e
	Total:	**9,437 - 23,315 tons biochar**		**18,874-46,630 tons CO_2e**

[6] Lehmann, J., & Joseph, S. (2015). Biochar for Environmental Management - Science, Technology & Implementation.

[7] Adapted from Iliescu, O., Jalas, M, and Salo, E. "Biochar benefits and potential applications in Greater Helsinki." Aalto University, May 2022.

Key Considerations

City governments are in a unique position to both catalyze and shape biochar production and use. Government officials and agencies – including Parks / Urban Forestry, Public Works, and Transportation – have the power to foster the aggregation of wood waste critical to regional production of biochar; furthermore, they can be large-scale purchasers that drive market demand, set specifications, and standardize commercial production among private sector biochar producers. As cities approach this role in guiding development of a circular economy around urban forest biomass utilization, the following considerations are offered as cornerstones of research and strategy development:

- **Carbon impact and efficiency.** Pyrolysis systems can vary dramatically in carbon efficiency, waste heat capture, and biochar yield from biomass. As a result, the carbon payback period can be an important metric in considering how long it takes for a process to become carbon negative – this can vary by an order of magnitude across different technologies. Production systems should be analyzed and evaluated based on metrics including capacity, cost, and net carbon impact. A sample analysis of biochar production systems by ARTi and Biochar Now can be found within the project resource library.
- **Safety and standardization.** Given the variability in quality and characteristics of biochars currently on the market, criteria such as feedstock, ash content, and stable carbon should be used to evaluate different biochars prior to procurement and use. For more detailed recommendations, see: "Biochar Guidance: Considerations for Municipal Procurement & Application."
- **Siting & transportation.** In order to maximize the carbon benefit of wood utilization, colocation of biochar processing to feedstock sources will play a role in the net carbon impact of the system. While zoning and permitting may constrain siting, locating infrastructure in as close proximity to the urban forest as possible and utilizing low-carbon vehicles for hauling biomass will help increase total carbon benefit.
- **Community justice & equity.** In order to combat a legacy of siting industrial activity in minority and low-income communities, it is critical that decisions regarding the selection and placement of biochar production infrastructure consider social and environmental impacts to the surrounding community, including the potential air quality impacts of both ongoing pyrolysis system operations as well as the associated trucking of wood in and out of the site. For more, check out Once & Future Green's Biochar Siting and Environmental Justice Guide for Cities and Communities.
- **Storage.** Storage of both raw input biomass and resulting biochar is critical to smoothing supply and demand fluctuations over time. However, it should be noted that the UN classifies biochar as a Class 4 Dangerous Good with respect to storage and transport, due to risk of ignition. Prevention methods identified by the International Biochar initiative include application of specific chemicals to reduce flammability, and storage/transport in an oxygen-free environment.[8]

[8] Iliescu, O., Jalas, M, and Salo, E. "Biochar benefits and potential applications in Greater Helsinki." Aalto University, May 2022.

Recommendations & Best Practices

Based on learnings from peer cities, the following recommendations are offered as best practices toward development of a biomass to biochar utilization program.

Support wood waste capture by centralizing collection infrastructure

A first step in efficient utilization of biomass from urban forest maintenance activity is the establishment of centralized collection points for of wood waste generated by tree care work (ie. logs, limbs, and brush. As disposal of this material often presents a pain point for local arborists, creation of a low or no-cost outlet can help alleviate this burden while ensuring that biomass is aggregated and directed into a pyrolysis process, rather than sent to landfill or left to decompose, releasing stored carbon in the form of greenhouse gasses. Additionally, policy interventions – such as requiring local arborists to report on annual wood waste generation or utilize designated collection points as part of the local licensing process – may ultimately be required to facilitate wider compliance.

Catalyze local demand for biochar

Sustainability of a biomass to biochar production system hinges on the development of ongoing application pathways for utilizing biochar in the city and surrounding region. As a result, fostering demand for biochar within public projects – such as stormwater management, urban agriculture, and tree planting projects – will be an important first step in establishing consistent demand. In addition to driving procurement as a purchaser of biochar, cities may consider development of carbon offsetting projects using a biochar production methodology.

Pilot and assess biochar impact potential

Because biochar's climate impact potential is subject to variables including selection of specific technology, further research is needed to quantify the efficiency of carbon and waste heat capture within a specific pyrolysis system. Transportation distances between source feedstock, processing, and application, will also play a role in determining the net carbon impact of a biochar production system. Finally, as non-carbon impacts such as increased water availability and pollutant remediation are variable according to local context and application practices, onsite evaluation will be necessary to validate and quantify environmental impact prior to large-scale program implementation. Additional resources regarding testing and laboratory analysis of specific biochars can be found via the International Biochar Initiative and the European Biochar Certificate.

Leverage local resources

Cities may benefit from collaborating with local research institutions – such as universities, and NGOs – to support development of biochar programs. In Minneapolis, the Natural Resource Research Institute (NRRI) and University of Minnesota have provided expertise and support in laboratory and field testing of biochars; similarly Aalto University and the VTT Technical Research Centre of Finland have been supporters of research and analysis of biochar potential in Helsinki. By collaborating with local institutions in the development of pilot projects and evaluation programs, cities can gain support in addressing knowledge gaps, while providing the technical evaluation needed to guide program scaling.

Similarly, collaborations with existing biomass energy and biochar production companies – can help foster opportunities to develop public-private partnerships focused on increasing the scale and efficiency of local biochar production, without requiring direct city oversight or ownership.