

Fact Sheet: Flame Cap Kilns

*Tools for turning woody debris into biochar
for lasting soil health and landscape resilience*



Flame cap kilns are a simple, portable, affordable tool to transform woody debris to biochar on-site.

Biomass—like branches, brush, and other woody debris—is often so widely scattered across landscapes that it is not practical or cost-effective to collect and haul it to a commercial facility for processing. This is especially true in forest management, where wildfire mitigation projects and timber operations create large amounts of low-value, leftover wood for disposal as waste, as well as agricultural properties with significant woodlands. Fortunately, there's a better solution: **we can turn this stranded material into biochar with flame cap kilns and use the biochar on site** – saving money, increasing resilience, and keeping carbon in the landscape for hundreds of years or more.

Flame cap kilns were first engineered in Japan, where farmers have long used simple, open containers to turn wood and bamboo into a carbon-rich material that improves soil. Often described as a “burn pile in a bin,” the flame cap kiln limits airflow just enough to turn biomass into captured biochar instead of ash. **This clean-burning process is called flame carbonization**, and in carbon markets, it's recognized as Biochar Carbon Removal (BCR).

While modern large-scale biochar systems often use afterburners or advanced controls to reduce polluting emissions, flame cap kilns work differently. They burn the smoke and volatiles in the flame, acting like a natural afterburner. Once the pile is reduced to glowing coals, it's quickly quenched with water to stop the burn and preserve the carbon. **This charred material isn't meant for fuel—when it's used to build healthy high functioning soils and landscapes and store carbon, it is called biochar.**

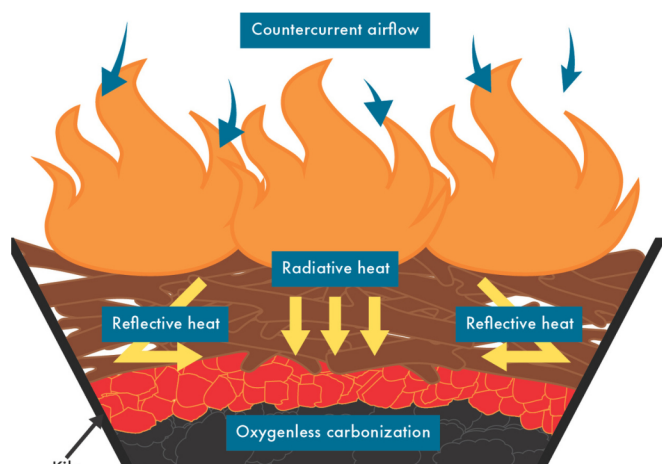


Biochar On Site



The Elegant Dynamics of Flame Cap Kilns

A flame cap kiln is a wide, open-top metal container designed to efficiently burn woody debris with low smoke. It's filled with dry material and lit from the top, which helps burn off gases and reduce emissions. As the first layer turns to glowing coals, more biomass is added in batches—starting light, then heavier, then tapering off as the kiln fills. Once it's full of hot coals and a light ash appears, the fire is quenched to make biochar. If the kiln has a sealed bottom, it can be flood-quenched with water (“drown quenching”). For kilns that sit directly on soil and are sealed at the bottom edge, the coals are typically extinguished through a combination of raking and spraying with water.



*A flame cap kiln closes off the bottom and sides of a burn pile to control oxygen. All the air comes from above (from *The Biochar Handbook*, Chelsea Green, 2024).*

Efficient counter-flow combustion:

- Gas flows upward and burns in a flame, while combustion air flows downward
- Burning fuel draws air down, creating a steady, controlled airflow that keeps the fire clean and efficient
- The flame cap stays low and stable, reducing the risk of escaping embers
- Smoke burns in the flame. Most smoke is consumed before it leaves the kiln
- Very little oxygen reaches the coals at the bottom, preserving biochar
- Once the flames die down, the biochar is preserved by extinguishing the hot coals

Unlike traditional open burn piles – commonly used to get rid of woody debris – flame cap kilns burn cleaner, safer, and with far less damage to the landscape. Instead of creating fire scars and air pollution, flame cap kilns convert much of the carbon from a short-term to a long-lasting form as biochar. These small, mobile, hand-loaded kilns are easy to operate and well-suited for dealing with hard-to-manage and hard-to-access piles of debris. Trained crews can convert up to 20% of the biomass into stable, carbon-rich biochar that stays in and improves the local soil.

Environmental and Community Benefits

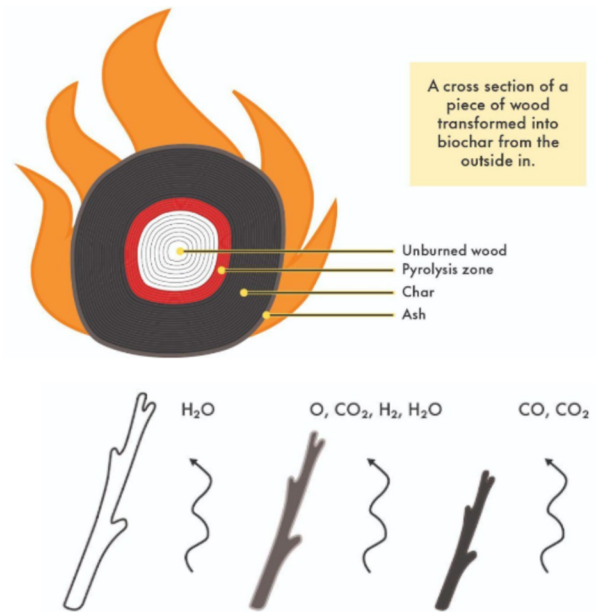
- **Reduces Wildfire Risk** – Burns thinning debris cleanly, without heavy smoke or particulates.
- **Improved Land Management** – Clears brush and invasives so native plants return stronger.
- **Locks In Carbon** – Biochar stores carbon long-term and improves soil health.
- **Holds Water** – Helps soil retain moisture and filter runoff, easing drought stress and improving water quality.
- **Brings People Together** – Group burns and hands-on workshops build skills, connection, and care for the land.



Combustion or Pyrolysis? How Biochar Forms.

Biochar is made through a process called pyrolysis, which means heating organic material in a low-oxygen environment. While it sounds technical, **pyrolysis is actually one stage of the natural burning process**. When a solid fuel like a stick of wood burns, it goes through several steps: first, moisture evaporates and escapes as steam. Then, flammable gases – made of carbon, hydrogen, and oxygen – are released and burn in the flame, creating intense heat. As this happens, a blackened, carbon-rich layer (biochar) begins to form on the surface of the wood. The heat continues to move inward, releasing more gases and creating more biochar – unless too much oxygen reaches the material, in which case it turns to ash instead.

Pyrolysis is one stage of complete combustion, and to make biochar, you simply need to cut off access to air before the process finishes and the wood turns to ash. **The red zone shown in the stick cross-section is where pyrolysis occurs, protected from oxygen.** Biochar, being a solid fuel, will only continue to burn if oxygen reaches it directly.



*Flame carbonization works by managing the three stages of combustion and stopping the combustion process before it completes and burns the biochar to ash.
(from The Biochar Handbook, Chelsea Green, 2024).*

Common Misconceptions

Open burning is often thought of as a highly polluting process that should always be avoided, yet often burning is the only practical solution for debris disposal. **Fortunately, with proper operation, the flame cap kiln alternative will burn efficiently, minimize harmful emissions, and produce stable, measurable carbon outcomes.** In fact, the flame cap process can be quantified accurately enough to meet the requirements of carbon credit protocols.



Who Uses Flame Cap Kilns?

- Farms, orchards, and vineyards
- Invasive species removal programs
- Educators and conservation groups
- Defensible space contractors
- Homeowner's associations
- Municipal land managers
- Storm cleanup crews
- Landowners
- Foresters
- Arborists



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Flame Cap Kiln Examples

- **Oregon Kiln:** Portable and suited for remote areas. Sealed bottom, uses a flood-quenching method. Free open-source design.
- **Cone/Kontiki Kiln:** One-piece cone design with a solid bottom can be easily flood-quenched. Basic plans available online.
- **Ring of Fire Kiln®:** Modular, extendable panel system that's easy to transport and set up on varied terrain. Open-bottom design.
- **Big Box Biochar:** Large-format kiln built for hazardous fuel reduction & biochar production. Free open-source plans.



What types of biomass work best in a flame cap kiln?

Because all air enters from above, feedstock must have enough air spaces to allow oxygen to flow down and gases to escape. Branchy material, or poles or chunks that do not pack together will allow the air to flow around the biomass. This means not all feedstocks can work in the flame cap kiln.

- ✓ Tree limbs
- ✓ Small logs (<15 cm diameter) or cordwood
- ✓ Brush and prunings
- ✓ Canes and bamboo
- ✓ Woody weeds (e.g., scotch broom, blackberry)

- ✗ Nut shells & rice hulls
- ✗ Leaves & needles
- ✗ Wood chips
- ✗ Manure
- ✗ Straw



About Biochar On Site

Biochar On Site (BOS) is a program focused on promoting the on-site production and application of biochar for ecological restoration. The program emphasizes using local, sustainably sourced, and unprocessed woody biomass to create biochar through appropriate methods. The mission is to normalize this practice, fostering regenerative land stewardship, mitigating wildfire risks, and increasing soil carbon for resilient ecosystems.

Learn more and find additional resources at biocharonsite.org

