

# **River Refugium Project (RRP)**

## **CERNUNNOS FOUNDATION**

## **BRIGHT MEADOW GROUP**

*Systems Analysis and Solutions Consulting*

---

**Document Title:**

**RRP5 HTC/HTL Thermochemical Processing**

**RRP Document Number:**

**RRP0002.6**

**Version by date time group:**

**01 APR 2026 0001**

Cernunnos Foundation / Bright Meadow Group

---

Email: [robert@brightmeadowgroup.com](mailto:robert@brightmeadowgroup.com)

Website: [www.cernunnosfoundation.com](http://www.cernunnosfoundation.com)

| **\*\*RIVER REFUGIUM PROJECT\*\*** Cernunnos Foundation Bright Meadow Group | **\*\*RRP5 – HTC/HTL Thermochemical Processing\*\*** Document No: RRP0002.6 | Version: 2.0 |  
01 April 2026 Status: Published – Version 2.0 | Supersedes: Version 1.0 (2025)  
\*Contact: robert@brightmeadowgroup.com	www.cernunnosfoundation.com\*

**\*\*Abstract\*\*** The HTC/HTL plant is the River Refugium Project's industrial backbone – the zone where biomass harvested from the greenhouse complex is transformed into fuels, hydrochar, energy, and closed-loop process water. Hydrothermal Carbonization (HTC) and Hydrothermal Liquefaction (HTL) are high-pressure, high-temperature processes that convert wet biomass into bio-crude, hydrochar, nutrient-rich aqueous phase, and off-gases. This document explains the process flow, operating conditions, and system integration logic. The thermochemical plant is present in Model A (on-site) nodes; Model B nodes transport biomass to a regional Model A hub.

#### # **\*\*1. Why HTC/HTL Is the Right Process for RRP Biomass\*\***

RRP biomass is produced in hydroponic systems – water-saturated, high-moisture, low-density, and difficult to dry without energy waste. HTC and HTL are uniquely suited because they require wet feedstock. This makes the processes energy-efficient, operationally compatible with algae slurry, low-loss in handling, and ideal for nutrient-rich sludge streams.<sup>1</sup> Without thermochemical conversion, biomass would accumulate, require drying, create odor and pathogen vectors, and introduce storage risk. The HTC/HTL plant converts all biomass on-site into stable, compact material – zero accumulating waste.

#### # **\*\*2. Feedstock Preparation\*\***

Incoming biomass – algae paste, cotton stalks, willow rods, jute, miscanthus – is shredded to a uniform particle size suitable for high-pressure conveyance.<sup>2</sup> Depending on moisture content, material becomes a pumpable slurry (algae), wet pulp (fiber crops), or blended mash (mixed biomass). Feedstock is staged in surge tanks to create a steady-state feed rate for the reactors. Uniform feed is critical for reactor efficiency and energy balance.

#### # **\*\*3. Hydrothermal Carbonization (HTC)\*\***

HTC converts wet biomass into hydrochar at moderate temperatures and pressures. Operating conditions: temperature 180–250°C, pressure 2–10 MPa, residence time 1–8 hours.<sup>3</sup> Under subcritical water conditions, cellulose and lignin break down, carbon densifies, solids separate from liquid organics, and gases form. Outputs: solid hydrochar, aqueous phase (dissolved organics and nutrients), and off-gases.

Hydrochar applications: soil amendment and carbon sequestration instrument; activated carbon precursor (premium market); filtration medium; biocomposite filler; substrate material for greenhouse root zones – closing the loop between thermochemical conversion and growing operations.

#### # **\*\*4. Hydrothermal Liquefaction (HTL)\*\***

HTL converts wet biomass into bio-crude at higher temperatures and pressures. Operating conditions: temperature 280–370°C, pressure 10–25 MPa, residence time 15–60 minutes.<sup>4</sup> High-lipid feedstocks such as algae are preferentially routed to HTL due to higher bio-oil yield. The feedstock split between HTC and HTL pathways depends on crop mix – in the current model, algae houses direct 80% of biomass to HTL while fiber and structural crop houses direct 60% to HTC. ▀ Actual split will be calibrated by pilot operations.

Bio-oil applications: refinery feedstock, chemical manufacturing, plastics production, adhesives, binders, lubricants. Globally tradable, ESG-favored, price-linked to petroleum markets.

## # \*\*5. Phase Separation \*\*\*\*&\*\*\*\* Energy Loop\*\*

Following thermochemical conversion, the process stream separates into solid (hydrochar), liquid (bio-oil or aqueous phase), and gas fractions. The aqueous phase – nutrient-rich water from both HTC and HTL – recirculates to the algae production houses, providing a nutrient input that reduces fresh water demand and closes the nutrient loop.<sup>5</sup>

Off-gases (methane-rich, CO<sub>2</sub>-rich) and waste heat from the reactors are captured and routed back to the greenhouse complex for enrichment and heating. No external heating or cooling energy is purchased – the system is thermally self-sustaining under normal operating conditions. This is a confirmed design characteristic, not a projection.

## # \*\*6. Model A vs. Model B\*\*

Model A nodes carry the full HTC/HTL plant on-site. Model B nodes transport harvested biomass to a regional Model A hub for processing. The cluster architecture – one Model A hub serving 5–10 Model B satellites – is designed to maintain reactor steady-state throughput across the aggregate biomass supply of the cluster.<sup>6</sup> This protects reactor maintenance cycles and eliminates feedstock variability risk from any single node's seasonal curve.

### \*\*Notes\*\*

\*Citations follow Chicago Notes-Bibliography style. Internal Bright Meadow Group / Cernunnos Foundation documents are cited by document title and year. Figures marked ■ are provisional academic proxies pending replacement by RRP pilot data per RRP8.\*

- \*\*1. \*\*Elliott, D.C. et al., \*\*\*\*Hydrothermal Processing of Biomass.\*\*\*\* Pacific Northwest National Laboratory, PNNL report, print edition.\*

- \*\*2. \*\*Bright Meadow Group, \*\*\*\*Biomass Feedstock Preparation Manual.\*\*\*\* RRP Processing Module Draft, 2025.\*

- \*\*3. \*\*Funke, A. and Ziegler, F., \*\*\*\*Hydrothermal Carbonization of Biomass: A Summary and Discussion of Chemical Mechanisms for Process Engineers,\*\*\*\* Journal of Analytical and Applied Pyrolysis 98 (2010): 107–117.\*

- \*\*4. \*\*Toor, S.S., Rosendahl, L., and Rudolf, A., \*\*\*\*Hydrothermal Liquefaction of Biomass: A Review of Subcritical Water Technologies,\*\*\*\* Energy 36 (2011): 2328–2342.\*

- \*\*5. \*\*Bright Meadow Group, \*\*\*\*Energy Integration \*&\* Heat Loop Strategy.\*\*\*\* CF/BMG Systems Design Notebook, 2025.\*

- \*\*6. \*\*Bright Meadow Group, \*\*\*\*RRP6 – Economic \*&\* Deployment Model,\*\*\*\* Version 2.0. CF/BMG, 01 April 2026. Section 4, Hub-and-Spoke Cluster Architecture.\*