The Consortium for Advanced Wood-to-Energy Solutions (CAWES) met to assess challenges and knowledge gaps relevant to the advancement of torrefaction technology. With an initial joint investment of $4 million, CAWES partners are embarking on a 24-month work plan aimed at validating torrefied wood as a promising renewable energy market solution.

Consortium for Advanced Wood-to-Energy Solutions: Kick-Off Workshop

Executive Summary

Atlanta, Georgia - August 2014

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U.S. Endowment for Forestry and Communities

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Consortium for Advanced Wood-to-Energy Solutions: Purpose

The Consortium for Advanced Wood-to-Energy Solutions (CAWES) is an open-platform collaboration of institutions in the public and private sectors representing green energy, forest management, research, philanthropy, and private industry committed to advancing sustainable, scalable, distributed wood-to-energy solutions that stimulate forest restoration and rural economic development through research and application of advanced wood-to-energy solutions.

Founding partners include the *U.S. Endowment for Forestry and Communities (Endowment), USDA Forest Service - Forest Products Laboratory (FPL), and Georgia Southern University's Herty Advanced Materials Development Center (Herty).* The Endowment and USDA Forest Service, State and Private Forestry Branch (Washington Office) have made a joint investment commitment of $4 million to "jump start" CAWES. This initial funding is designed to accelerate the commercialization of torrefaction-based technologies as an environmentally and socially acceptable, economically viable, market-based solution for forest restoration in rural forest-rich communities. CAWES partners will help identify and support critical research and information needs and aid the launch of two or more commercial partner operations – likely one in the eastern U.S. and another in the western U.S. Each location will serve as a "living laboratory" for commercial evaluation of torrefied product in industrial and utility facilities.

What is Torrefaction?

Torrefaction is a mild form of pyrolysis—a thermochemical process to decompose organic material at elevated temperatures in the absence of oxygen. The process drives off water and volatile compounds from biomass leaving a more energy-dense product. A major challenge facing the commercialization of torrefaction-based technologies is the cost of transporting this material due to inherent low bulk density. Methods for densifying torrefied wood to increase its bulk density will significantly lower the transportation costs of torrefied wood and open new markets.

When densified into a pellet or briquette form, torrefied wood is superior to other forms of biomass because it handles much like coal while retaining all the benefits of a renewable and sustainable bio-based fuel. Torrefied pellets or briquettes exhibit properties that should allow co-firing with coal or direct substitution as a drop-in boiler fuel without system modifications. They also have the advantage of requiring lower grinding energy compared to white pellets.

Studies reveal torrefied wood is an effective soil amendment. It sequesters carbon and improves soil properties, thus reducing fertilizer use and runoff. Due to a higher energy density, torrefied wood could improve the biomass logistics infrastructure needed to support the nascent biorefinery industry, as well as the production of transportation fuels and bio-based chemicals from renewable and sustainable sources of forestry biomass.

Becoming a CAWES Partner

CAWES expects to bring the best minds in private development, government, academia, and conservation together to accelerate appropriately-scaled commercialization of wood-to-energy technologies. Members will receive non-exclusive, royalty-free access to all intellectual property developed by the Consortium with opportunities for intellectual property-protected work under special agreements. The challenges and knowledge gaps identified by CAWES partners will form the foundation for funding priorities and benchmarks.

The founding partners seek the participation of any institution – whether public or private – that shares a commitment to addressing the challenges and opportunities torrefaction presents. Partner organizations will make an entity-appropriate annual financial contribution and serve on the Steering Committee or one of two advisory boards. The consortium will meet quarterly.

CAWES Organizational Structure

Steering Committee:	Founding members and one representative from each consortium member
Scientific Advisory Board:	One representative from each research affiliate member
Sustainability Advisory Board:	One representative from each stakeholder affiliate member along with identified environmental and social technical experts

State-Of-Torrefaction Technology: Some Take-Aways

"Catalytic investment can change the world."
Carlton Owen, CEO, Endowment

The CAWES' Kick-Off Workshop participants met in Atlanta, GA on August 26-27, 2014 and helped set the stage for launching a roadmap to assess torrefaction as a biofuel source for the future.

All agreed that the consortium should pursue applied research that helps fill information gaps aimed at reducing risks, accelerating speed to market, and delivering industrial scale product. All research will occur in the context of appropriately assessing and addressing environmental and societal risks. Coordinated government, university and private research is recognized as critical to solving the remaining material, structure, transportation, storage, and efficiency issues facing commercial scale production.

As the sector develops, CAWES will promote a collegial atmosphere where researchers and developers may view each other as co-learners versus competitors.

Major Take-Aways and Insights

- Torrefied wood has significant market potential as a hydrophobic, densified energy carrier that stores, travels, and functions much like coal.
- If properly engineered, an energy carrier derived from torrefied forest-based biomass could support a new source for sustainable, bio-based energy.
- Coal-fired utilities in the U.S., which consume nearly 860 million tons per year of coal, looking to reduce their environmental impact and greenhouse gas emissions could benefit greatly by the adoption of torrefied wood as a replacement or co-firing material for coal.
- Torrefied wood can have the physical properties of coal, but not necessarily the chemical properties. Feedstock and the type of torrefaction process influence these qualities. Nonetheless, torrefied wood has a significantly lower sulfur content than coal, which is expected to lower the emission of regulated sulfur dioxide (SOx) emissions.
- To date, a true commercial-scale facility that fully integrates torrefaction and densification does not exist. This development would enable product introductions and establishment of markets for torrefied wood.

- Technology developers are experimenting with various forms of densification, including pellets and briquettes. However, technical barriers such as the processing conditions on material properties have thwarted the ability to produce a consistent densified product that meets customer expectations for performance and transportation.
- Establishing a robust supply chain and associated logistics is a significant part of the commercialization equation: supply access, classification of feedstock, adequate storage, and capacity within the forest products delivery business sector. Some suggest co-locating torrefaction and pellet manufacturing to simplify access to the resource, delivery, and sorting.
- Issues related to feedstock classification and sourcing must be addressed, including how to utilize urban wood waste.
- Establishing long-term supply agreements for biomass sourced from public lands will be critical to stimulating commercial interest for torrefaction projects in the Western U.S.

"Customers of Consequence" for Torrefied Wood

- Utilities are most likely the primary client for a scaled-up torrefaction industry. Without the involvement of the utility sector, it will be difficult to ramp-up torrefaction production.
- There are other potential markets for torrefied wood – biochar as a soil amendment and activated carbon as a water filter medium, among them – but the utility sector holds the greatest promise for scale at this time.

"There are at least seven approaches to torrefaction and all the technology providers are represented at this table. By focusing on the big market opportunities, like electric power generation, we can really jump-start this industry. "

- Atlanta Participant

Standards and Lessons from Others

- Standards will be imperative to gaining the social license as well as access to growing European markets looking for bio-based energy solutions. The Pellet Fuels Institute has gone through an involved process of developing codes and standards for pellet manufacturers. Many similarities in the two industries suggest opportunities to learn from the pellet makers.

- The Belgium based International Biomass Torrefaction Council has developed a host of work in standards and specifications development. European partners could aid in addressing barriers to trade.

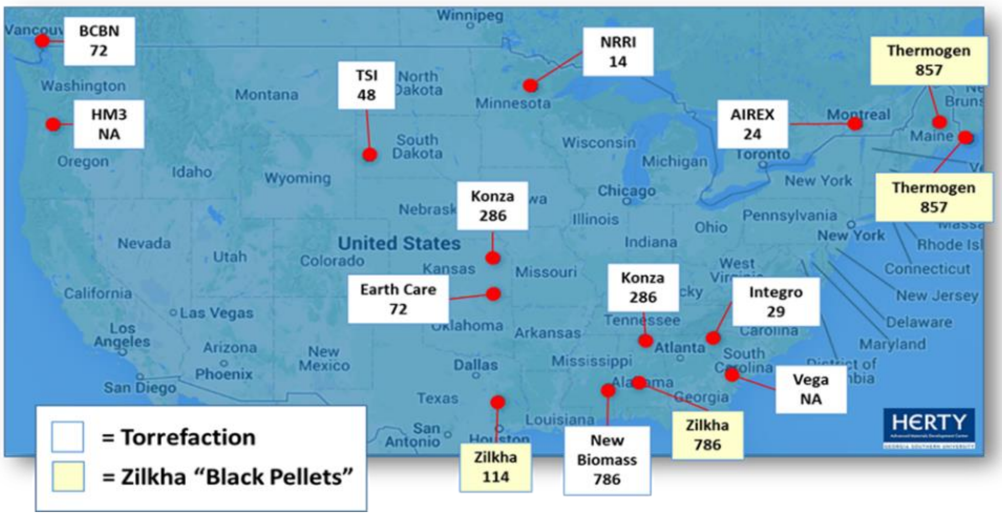
Resources

- The USDA Forest Service, State and Private Forestry branch is drafting a matrix of government programs relevant to woody biomass. An existing list - Woody Biomass for Energy Summary of Federal Programs Available for Business Enterprises - updated in 2010, is posted on the Endowment website.

- The work of William Strauss, Future Metrics, is considered a good source of information to compare torrefied product with other woody biomass-based fuels.

Torrefaction and Black Pellet U.S. Capacity

The conventional wood-based energy pellet industry is rapidly expanding. Driving this growth is exports, which according to a recent Energy Information Administration study have doubled from 1.6 million tons per year to 3.2 million tons per year. In contrast, advanced energy carriers, specifically those made from torrefied wood or steam exploded wood, developed by Zilhka Biomass, have been limited to pilot-scale. According to a recent analysis by Herty, capacity for torrefied wood production is less than 400 tons per day. However, announcements in both torrefied wood and steam exploded wood facilities are over 4,200 tons per day (1.5 million tons per year). North American capacity, known at the time of the Atlanta meeting, is shown below (in tons per day).



Wood-to-Energy Limiting Factors - Torrefaction

In order to develop robust community-scale markets for low-value wood that contributes to forest health, landowner income, reduced environmental risks, and domestic renewable energy, a high-density, easy to manage product is needed. Torrefied wood offers promise for a near-term option.

This draft matrix will aid in the evaluation and monitoring of CAWES investments. Results from the CAWES "Knowledge Gaps and Challenges" survey will serve to refine this tool.

Limiting Factor	-2 Prevents	-1 Limits	Not Limiting	1 Enabling
PUBLIC POLICY				
1. Government incentives for development of advanced wood-to-energy products	Public policy, laws or regulations provide a direct disincentive that impedes development of torrefied products.	Public policy, laws or regulations don't provide equal incentives for torrefied and/or other woody biomass energy products versus other renewables.	Public policy, laws or regulations provide equal incentives for torrefied and/or other woody biomass energy products versus other renewables.	Public policy, laws or regulations provide greater incentives for torrefied and/or other woody biomass energy products in appropriate circumstances versus other renewables.
2.Environmental laws & regulations	Environmental laws and regulations *prohibit* development of torrefied products at scale due to actual or perceived air quality or other environmental, health and safety impacts.	Environmental laws and regulations *impede* development of torrefied products at scale due to actual or perceived air quality impacts or other environmental, health and safety impacts.	Environmental laws and regulations treat torrefied products on a *consistent* scientific basis with other forms of energy products AND torrefied products generate comparable air quality and environmental, health and safety impacts to products they replace.	Environmental laws and regulations exhibit a preference for torrefied products on scientific merits AND torrefied products generate fewer air quality and other environmental, health and safety impacts to the products they replace.
STAKEHOLDER SUPPORT				
3. Public opinion (environment)	The public broadly *opposes* torrefied products on the basis of real or perceived environmental or economic issues.	Public opinion is *mixed, with notable opponents* to torrefied products on the basis of real or perceived environmental or economic issues.	Public opinion is *neutral* to use of torrefied products.	The public broadly supports uses of torrefied products based on the real or perceived environmental and/or economic benefits.
MARKET FORCES				
4. Domestic Market	Domestic market shows *no demand* for torrefied products.	Domestic market shows *limited demand* for new torrefied products.	Domestic markets operate *without preference* for/against torrefied products.	Domestic market *preferentially demands* torrefied products.
5. International Markets	Anticipated international markets *don't emerge*.	International markets *develop only modestly* providing limited economic benefits.	International markets – especially Europe and Asia – express a *growing demand*.	International markets exhibit *robust growth and expansion*.

6. Access to Capital	Access to capital for community-scale or modest-sized industrial facilities is not available.	Access to capital for community-scale or modest-sized industrial production facilities is available but difficult to access.	Capital for community-scale or modest-sized industrial production facilities does not differ from that available to other energy products.	Capital is preferentially available for community-scale or modest-sized industrial production facilities.
7. Raw Material	Sourcing, gathering and transporting low-value wood is so costly as to make feedstock non-competitive with other fuel sources, including (costlier) renewable alternatives.	Sourcing, gathering and transporting low-value wood is costly but not enough to make it non-competitive with (costlier) renewable alternatives.	Costs of sourcing, gathering and transporting low-value wood are competitive with both conventional non-renewable and renewable alternatives.	Wood fuel is lower cost than both conventional non-renewable and renewable alternatives.
8. Market Penetration	Widely scattered installations make wood-supply (e.g. delivery) unviable.	Modest levels of clustering reduce viability of delivery, but may encourage some suppliers to innovate.	Improvements in clustering of facilities make wood supply and delivery a non-issue.	Clustering and or linked distribution generates economies of scale that promote further adoption of wood fuel.
9. Support services	The one-off nature of consuming boilers makes production of a consistent torrefied product infeasible or too costly.	Existence of a number of like-kind consumers makes production of a consistent torrefied product feasible but costly.	A wide array of consuming facilities is capable and willing to use torrefied products.	Torrefied products, because of their favorable cost and environmental benefits become the preferred substitute fuel.
10. Payments for Ecosystem Services	Markets for the ecosystem service benefits of torrefied wood – enhanced forest and watershed health, etc. – do not emerge.	Markets ecosystem service benefits of torrefied products offer modest gains to overall market viability.	Markets emerge that account for significant accretive economic value.	Markets fully compensate forest owners and product producers for the full range of ecosystem benefits generated.
TECHNOLOGY RISK				
11. Technology Readiness	Technology solutions proven at bench scale. (TRL = 3-4)	Technology solutions proven at the pilot scale. (TRL = 5-7)	Technology solutions proven at the pilot scale. A risk management plan developed and risk is considered acceptable. (TRL = 7-8)	Technology solutions are commercial and support proliferation. (TRL > 9)

Torrefaction Success Factors

Rusty Dramm, FPL - Forest Products Marketing Unit, reviewed the following generic list of success factors:

1. Raw material resource availability
2. Product options from available resource
3. Market feasibility and marketing plan
4. Processing & manufacturing technology
5. Business management "know how"
6. Financial feasibility, available financing
7. Environmental, health & safety concerns
8. Social license

Advancing Torrefaction: Key Research Questions

Workshop participants generated the following lists of challenges and knowledge gaps across a series of key issue areas. The list will be refined via a survey instrument to ensure that limited resources (time, human and financial) are directed to topics of greatest importance.

What are the biggest challenges and knowledge gaps concerning Feedstock Supply and Logistics?

RESOURCE

1. Availability of raw material
   a. By type -- green wood; urban tree waste; mill residuals; short-rotation woody crops

2. Consistency (and guarantee) of raw material supply
   a. By source – public or private
   b. Long-term supply contracts

3. Cost of raw material

4. Feedstock type and variability
   a. Hardwood/Softwoods or mixtures; slash (bark, needles/leaves); mill residuals; moisture content (in-woods or pre-drying); consistency of size, etc.; quality

5. Using "habitat restoration" material (*e.g.* juniper) to aid endangered species habitat needs

6. Resource sustainability
   a. Higher & better uses questions (competition for raw material)
   b. Forest health
   c. BMP guidelines for harvesting and/or certification
   d. Potential to tap into 'disadvantaged producer" or "urban waste" programs

LOGISTICS

1. Business model
a. Distributed vs centralized facility
b. Facility size: small scale (10-100 tpd) or large scale (>100 tpd)

2. Timber harvesting/hauling infrastructure

3. Haul distance from raw material supply to facility

What are the biggest challenges and knowledge gaps concerning Conversion and Densification?

CONVERSION

1. Product selection: Energy pellets/bricks, biochar or activated carbon

2. Technology/equipment selection
a. Mobile, modular, or permanent
b. Single or multiple production lines

3. Raw material quality
a. Biomass moisture content
b. Ash content
c. Species/blends

4. Torrefied wood energy density

5. Co-op model with multiple torrefiers sharing a densification facility

DENSIFICATION

1. Need to prove densification of torrefied wood at scale

2. Pellet/Briquette integrity
a. Use of binders
b. 100% hydrophobic or water resistant

3. Product qualifications
a. Life Cycle Analysis
b. Environmental Product Declarations
c. ISO or other standards (uniformity/consistency of quality)
4. Special shipping/transit needs for torrefied product

CONVERSION & DENSIFICATION

1. Throughput and scalability (tons per day)

2. Off gases /air quality

3. In-line, real-time monitoring of quality

4. Pilot scale demonstration facility availability for producers and users (testing)

5. Worker safety issues
   a. Dust
   b. Fires

6. Plant Engineering studies available

What are the biggest challenges and knowledge gaps concerning Markets and Economics?

Markets and Economics

1. Generic business case development/availability
   a. Business case sensitivity analyses available for costs and scale of production
   b. Price targets to compete with coal, natural gas and petroleum known and achievable
   c. Powerful business proposition
   d. Issues solved with product
   e. Government policies

2. Credible market analysis availability
   a. Demonstrated ability of torrefied wood to perform as a drop in coal substitute
   b. Demonstrated ability of torrefied wood to perform as a soil amendment

3. Off-take agreements with customers
   a. Amassing enough materials to supply consistent customer needs
   b. Utilities, heavy industrial, institutional

4. Competition from alternative woody biomass uses (chips, pellets, CHP)

5. Product standards and acceptance in place
   a. Credible product MSDS and EPDs available

6. Storage performance of product (*e.g.* outdoor/uncovered)

7. Test runs in electric utility and CHP facilities
   a. Effects on cost, GHGs, and energy production determined

8. Develop “story line” of social/environmental benefits

What are the biggest challenges and knowledge gaps concerning Regulatory and Social Challenges?

SOCIAL

1. Retaining the social license to remove and utilize woody biomass and hazardous fuels

2. Life cycle inventory and LCA for energy consumption and GHG emissions

REGULATORY

1. Production facilities
a. Understanding/meeting any EPA permitting regs or needs beyond state air and water quality issues/information needs in building/operating production facilities
b. Understanding/meeting any special OSHA regs
c. Discussions with EPA about overall product benefits

2. Customer facilities
a. Impacts on permitting issues for users of torrefied wood in utility and CHP operations
b. Any special handling of ash from utility operations

3. ENGO/public concerns
a. Carbon neutrality and/or impact
b. Sourcing from public lands
c. Impact of residual material removals on soil quality

4. Impact of bio-char amendments on soil quality

5. Certification needs/standards for product

6. Special maritime regulations on transport of torrefied products

7. Unleveled playing field
a. Subsidies for competing products

8. Executive Order to test product in federal facilities

What are the biggest challenges and knowledge gaps concerning Finance?

PLANNING

1. Clear understanding of CAPEX/OPEX per ton of annual installed capacity targets

2. Access to capital

3. Credible market studies available for torrefied wood, biochar, and activated carbon

4. Business cases ROI and ROCE projected/ determined

5. Targeted site selection criteria to optimize federal, state, local incentives

6. Developing a compelling and easily understood communications plan

7. When comparing/contrasting with coal/natural gas, etc., make sure the examples are regionally specific and tied to specific fuel type (e.g. lignite vs. anthracite)

8. Economies of scale developed/known

FUNDING OPTIONS

1. Use New Market Tax Credits

2. Engage Rural Development/Rural Innovation programs

3. Use EB5 funds

4. Government loan guarantees or low-interest loans for rural development

5. Joint-venture with end user

6. Get TIMOs/REITs as investors to create new market outlet for low-value wood

7. Look for special state incentives (e.g. SC "investor tax credits")

REGULATION

1. Expand liquid fuels incentives to cover solid fuels

2. Relax regulations on investment of personal retirement savings in controlled businesses

CAWES Partners Needed

Atlanta participants identified areas of expertise critical to the mission, in addition to those already at the table.

Associations

- Biomass Power Association
- European Biomass Association
- Pellet Fuels Institute
- Biomass Thermal Energy Council
- National Alliance of Forest Owners
- National Association of State Foresters

Investors

Forest Products-Related Business

- Local loggers (stewardship contractors)
- Pellet mills
- Primary product mills

Government

- Department of Energy- Biomass R&D Technical Advisory Committee
- Oakridge National Laboratory
- EPA Re-Powering America's Land
- USDA Forest Service Woody Biomass Coordinators
- Policy makers

Universities

- Michigan Tech University
- University of British Columbia

Environmental and Conservation Organizations

- National Wild Turkey Federation
- The Nature Conservancy
- National Wildlife Federation
- Environmental Defense Fund

CAWES Background and Overview

America's forests are a vital natural resource. They cover one-third of the nation's lands and yet more than one-half of our forests – both public and private – are in decline and in need of treatment to restore forest health and address stocking issues. These forest conditions are being driven by declining demand for traditional wood-based products, changing climactic conditions, endemic and exotic pests and diseases, and the need for policies that support both cost-effective and environmentally desirable market-based solutions. The loss of one-third of the nation's solid wood products manufacturing facilities (sawmills) and more than forty percent of pulp and paper mills (since 1990) have greatly diminished market outlets and options to utilize forest biomass from forest restoration operations. Further, this loss has in turn led to the loss of more than 500,000 family-wage jobs in rural communities.

Deteriorating forest conditions and limited market options have led to increasing size, intensity, and acreage of wildland fires that are collectively consuming more than $3 billion in federal tax dollars annually in suppression costs and billions more in economic and environmental loss as well as loss of human life. Large volumes of the forest biomass (e.g. small diameter, disease and insect killed, slash, and non-commercial species) that need to be removed are of no- or extremely low commercial value for the production of traditional wood-based products. Currently, this byproduct material from forest restoration operations is stacked, dried and eventually burned in place. Lack of commercially viable outlets for these no/low-value materials severely restricts the acres of forest restoration due to the high forest management costs incurred. Distributed wood-to-energy markets that can provide an economic outlet for these no/low-value materials are viewed among the best options to turn the curve against growing fire-related losses while opening up new markets that can help mitigate at least some of the forest products job and value-creation losses.

The Endowment approached the Forest Service and Herty to create a virtual entity that can address research needs and work with emerging companies to evaluate with speed the potential of advanced wood-to-energy solutions as a significant response to the challenge. The preceding founding partners have agreed to focus initial activity on torrefaction as the best near-term solution. It holds great promise for distributed production of biomass-based fuels derived from no/low-value forest restoration byproducts.

The partners believe that the best way to test fully and advance torrefaction opportunities is to establish an open-platform approach to both research and applied commercial operations. FPL and Herty will, with other allied research partners, address the range of science-based and evaluation needs to enable rapid development of torrefaction. At the same time, at least two emerging commercial/applied partners – one in the eastern U.S.; another in the western U.S. – will serve as the “living laboratories” to produce commercial quantities of torrefied material for commercial evaluation in a range of utility and energy-production facilities.

To the maximum extent practical, the partners plan to share pre-commercial information as broadly as possible. Still, there will be areas where specific work must be proprietary to protect the investments of the commercial partners.

<u>CAWES founding partners</u>:

Herty Advanced Materials Development Center (Herty), Georgia Southern University, Savannah, GA

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