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**AMMTO & IEDO JOINT PEER REVIEW**

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# EEII: Forest Products Programmatic Summary

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IEDO

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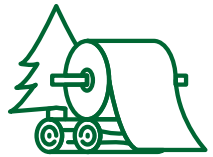
# Forest Products Industry Overview

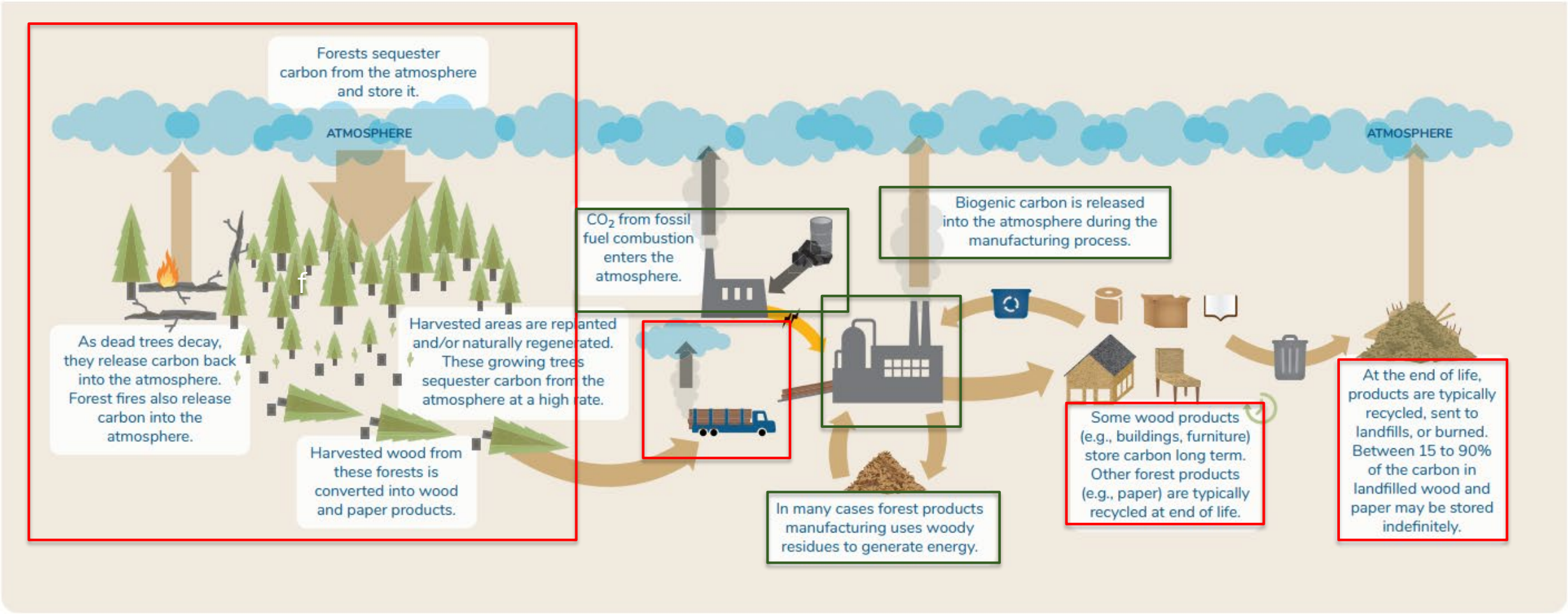


- Revenue - $350 billion annually, 5% of US manufacturing GDP
- Employment - 925,000 people, payroll of $65 billion
- Utilize fiber from sustainably managed forests and recycled resources
- Supply 60% of energy needs from biomass waste
- Capital intensive and “energy-intensive, trade-exposed”

| | Employment | Manufacturing Output (Billion) | Annual Compensation (Billion) | Facilities |
|---|---|---|---|---|
| Forestry & Logging | 117,900 | | $3.6 | |
| Wood Products | 452,900 | $154 | $28 | 775 |
| Pulp & Paper | 355,000 | $198 | $32 | 319 Mills / 3,440 Plants |

1. American Forest & Paper Association https://www.afandpa.org/about-afpa data from Bureau of Economic Analysis

# Biomass Carbon Cycle

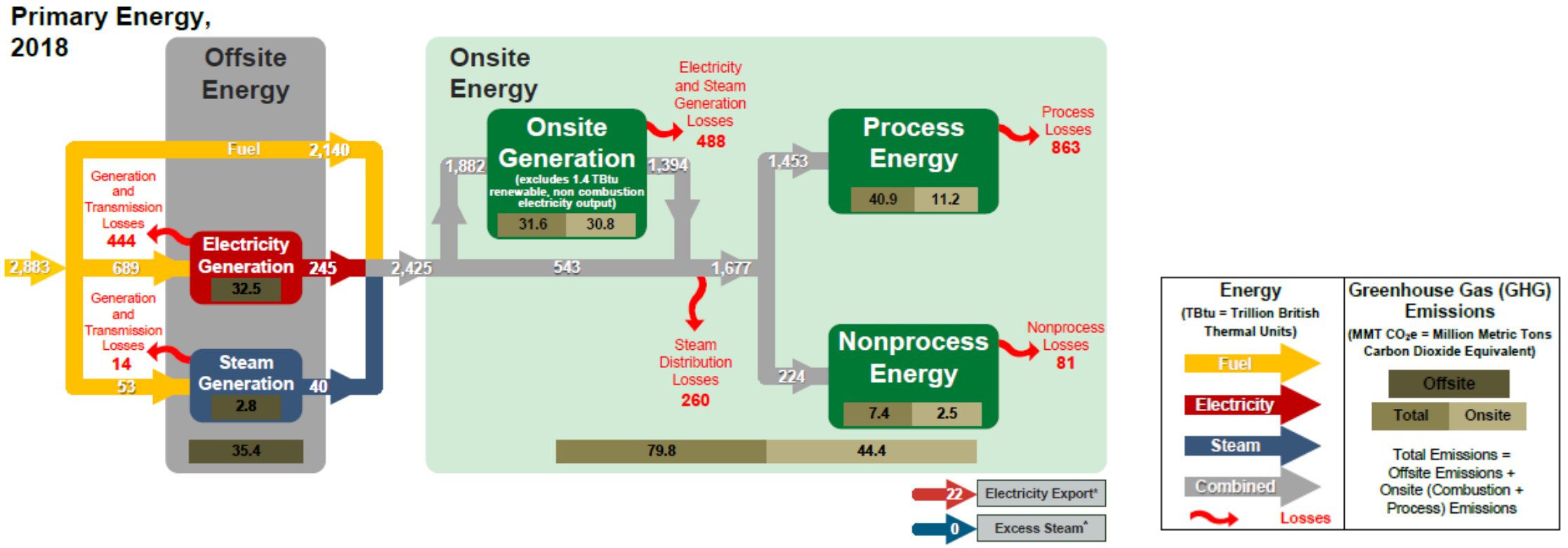



National Council for Air and Stream Improvement, Inc.
https://www.ncasi.org/resource/biomass-carbon-cycle-diagram/

IEDO Primary focus

# Energy and Carbon Footprint

**Primary Energy Use: 2,883 TBtu**
**Total GHG Emissions: 80 MMT $CO_2e$**

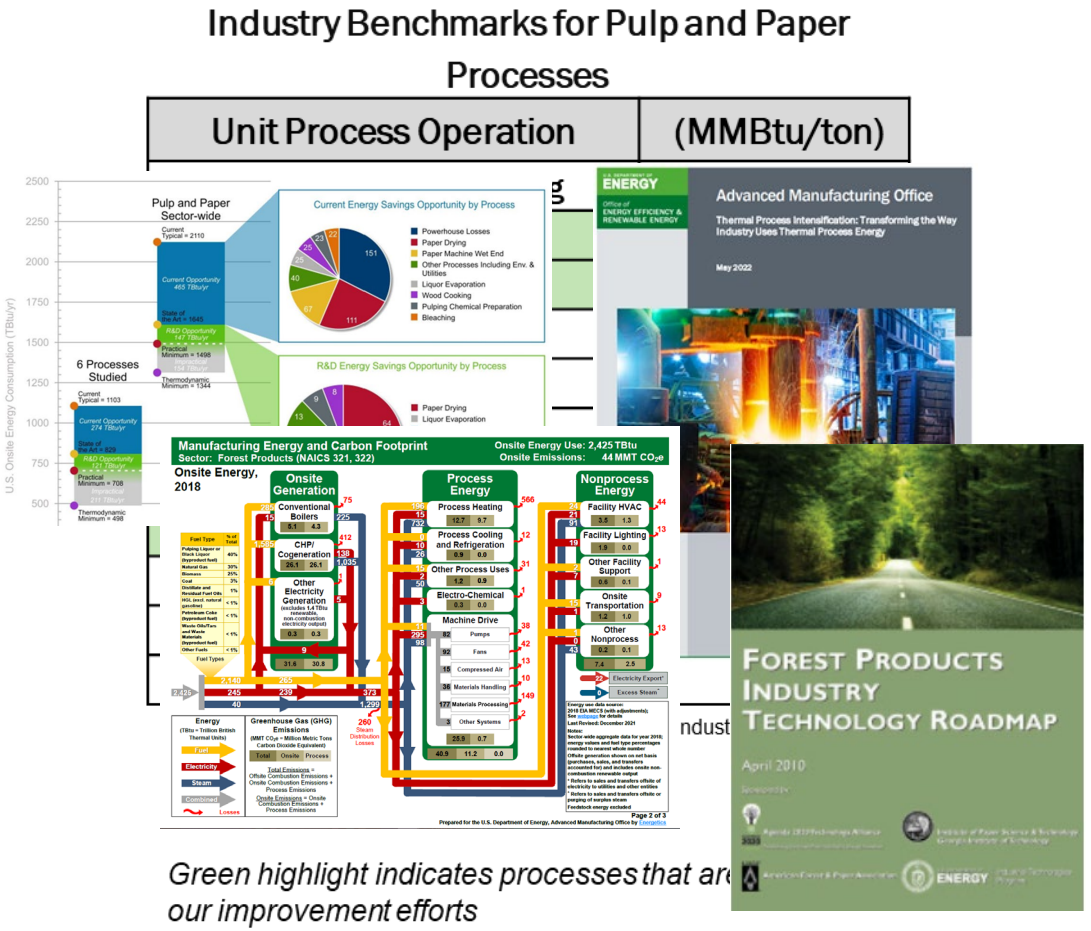



Prepared for the U.S. Department of Energy, Advanced Manufacturing Office by Energetics

| | | Black Liquor | Natural Gas | Biomass | Coal, other |
|---|---|---|---|---|---|
| Onsite Fuel | 2,140 TBtu | 40% | 30% | 25% | 5% |
| Onsite Emissions (fossil) | 44.5 M mt $CO_2$ | | 82% | | 18% |

# Strategy (Forest Products Industry)

- **Accelerate, through focused RD&D investments, the readiness of emerging, technologies to reduce energy use and carbon emissions from the forest products manufacturing**
- **Approach**
  - Understand current state (energy use, emissions, fuel sources)
  - Identify best available technology and technical challenges
  - Fund development of next-generation concepts and emerging low carbon technologies to reduce process energy use in high energy demand operations




*Green highlight indicates processes that ar*
*our improvement efforts*

# Technology Approaches to Net Zero *scope 1 fossil emissions only*

| | Emissions Reduction Approaches | |
|---|---|---|
| Mfg. Process | Improve operational and energy efficiencies with **cost-effective commercially available technologies** | |
| | Develop **technology upgrades and new breakthrough technologies** to reduce process energy use in **high energy-demand operations** | EEII Focus |
| | Convert natural gas/oil to **alternative fuels for lime kiln** (biogas or pulverized wood), **Oxy-fuel combustion with carbon capture** and sequestration, electric kiln | |
| | Low carbon fuel in **direct fired process** heating/drying applications | |
| Energy Generation | Increase the portion of energy generated from **biomass combustion** | |
| | Utilization of **other low carbon fuels or renewable electricity** to generate steam | |
| | Post-combustion carbon capture and sequestration from fossil fuel boilers | |

Green – Industry can do - technical assistance
Orange – RD&D needed

Energy Efficiency

Industrial Electrification

Low-Carbon Fuels, Feedstocks, and Energy Sources

Carbon Capture Utilization and Storage

# FPI Program Priorities

**Objective: Develop technology upgrades and new breakthrough technologies to reduce process energy use in high energy demand operations**

**Target: 20% reduction in fossil emissions, 6.8 M mt $CO_2e$**

| Key Activity | FY23 Focus | Future Focus |
|---|---|---|
| Innovative Paper-Forming and Novel Dewatering / Drying Technologies | • Increasing press solids<br>• Drying thermal efficiency<br>• Alternate energy sources<br>• Waste heat recovery | • Beginning to build portfolio<br>• Future priorities to be determined based on project portfolio success<br>  ○ Technical feasibility<br>  ○ Economic viability<br>  ○ Scale-up barriers<br>  ○ New issues identified |
| Innovative Fiber Preparation, Pulping, and Chemical Recovery Processes | • Lower-energy refining approaches<br>• Reducing energy/emissions in preparation of pulping chemicals<br>• Reducing energy use in pulping<br>• Reducing energy use and improving quality of recycled fiber | |

# Stakeholder and Collaborator Engagement

- **Stakeholder workshop – September 2023 - Explore opportunities for collaboration with industry and particularly with OEMs**
  - To inform IEDO's priority RD&D goals and metrics.
  - To identify the barriers and challenges
  - To identify opportunities to provide technical assistance that will support the sector.
- **DOE-wide initiatives, portfolio analysis, technology assessments, and stakeholder technical workshops will continue to refine and inform future priorities.**
- **Collaboration with offices across DOE (BETO, OCED, FECM, etc.) and participation in inter-office working groups will further inform priorities and coordinate activities.**

# Questions?

## Forest Products Industry – Program Summary

**David Turpin, Principal Consultant, Nexight Group**

**IEDO**

# Technology Development Approaches – Process

| Approach<br>*(Energy MM Btu/ton, %)* | Efficiency | LCFFES | Electrification |
|---|---|---|---|
| Reduce $CO_2$ emissions arising from energy use in **drying** of paper and wood products<br>*(4.6, 17%)* | *Eliminate rewet, increase press solids, increase drying efficiency, reduce water retention* | *H2 to replace natural gas in direct fired driers* | *Electric drying technologies RF, US, IR, MW.*<br><br>*Waste heat recovery, high-lift heat pumps. novel heat pump systems (absorption, etc.)* |
| Reduce energy use to reduce carbon emissions associated with **black liquor concentration**<br>*(3.5, 13%)* | | | *Graphene Oxide membrane materials and systems* |
| Increase fiber yield and reduce energy use in **pulping** to reduce CO2 emissions<br>*( 2.6, 9%)* | *Kraft alternatives (Deep Eutectic Solvents DES); Kraft improvements (pre-treatments, DES, catalysts)* | | |
| Reduce energy use to reduce $CO_2$ emissions from **wet end operations**<br>*(2.1, 8%)* | *Refining efficiency improvements, refining alternatives, less water in forming* | | |

# Challenges and Barriers – Process Approaches

Reduce carbon emissions (direct and indirect) resulting from paper drying (4.6 MMBTU/ton) and wood products drying.

| Approach | Barriers | Technical Challenges / R&D Needs | Technology Metrics | Priority |
|---|---|---|---|---|
| Increase the solids content of the paper web exiting the press section by ~20% (45-55% up to 65% solids) | Fiber damage, delamination, densification, hydrogen bonding | • New approaches to optimize pressing process variables to improve paper dewatering and reduce rewet<br>• Radically improved advanced pressing technology, like shoe press is or like impulse drying was supposed to be.<br>• Increase the dewatering and drying rate of the paper while maintaining performance parameters such as strength. | Solids content, Drying energy intensity *(lb $H_20/ft^2$-hr, lb steam/lb prod)* | High |
| Increase thermal efficiency of the traditional multi-cylinder paper machine dryer section and wood drying kilns. | Operational risk, downtime to install, 185C steam temp, | • Develop more energy efficient thermal drying equipment.<br>• Develop approaches to utilize alternate mechanisms of energy transfer for drying such as ultrasonic energy, radio frequency radiation, infrared radiation, etc.<br>• Develop processes to cost-effectively capture energy lost from the paper and wood drying processes and reuse the energy. (e.g., high-lift heat pump, absorption heat pump)<br>• Evaluate, revisit the feasibility of superheated steam drying | Drying energy intensity *(lb $H_20/ft^2$-hr, lb steam/lb prod)* | High |
| Eliminate fossil fuels in direct fired dryer applications (coating, tissue) | Natural gas readily available and low cost; H2 availability?, Burner performance, safety | • Develop burner technologies to safely utilize non-fossil sources of energy (e.g., H2) in direct fuel applications. | Emissions *~ 5 M mt CO2e, 6 % of fossil fuel use* | Medium |

# Innovation Approaches – Process / Energy Generation

| | Targeted Emissions Reductions from: | | | |
|---|---|---|---|---|
| **Approach** | **Efficiency** | **LCFFES** | **Electrification** | **CCUS** |
| Eliminate $CO_2$ emissions from fossil fuel use in **lime kiln** | | *Biogas, Pulverized Wood* | *Electric Kiln* | *Oxy-fuel combustion with CCS* |
| Eliminate/reduce $CO_2$ emissions from **fossil fuels used in steam generation** | *Improve heat integration via process intensification* | *Fuel switching – (1st) coal to natural gas, (2nd) NG to Biomass. $H_2$, RNG* | *Electric boilers* | *CCS power boilers* |
| Reduce/eliminate CO2 associated with **purchased electricity** | | *Reduce purchased electricity by using more biomass for electricity generation** | | |
| Eliminate CO2 emissions from **recovery boiler / wood waste boilers** | | | | *CCS from recovery boiler / wood waste boiler* |

**What opportunity exists for the industry to provide renewable electricity to the grid from biomass?*

# Challenges and Barriers – Process Approaches

Increase fiber yield and reduce energy use in wood delignification in order to reduce $CO_2$ emissions (2.56 MMBTU/ton)

| Approach | Barriers | Technical Challenges / R&D Needs | Technology Metrics | Priority |
|---|---|---|---|---|
| Develop more energy efficient and environmentally friendly alternatives to the kraft process for delignification | Strength, solvent recovery, lignin isolation and recovery, capital cost, integration, lowers bioenergy production | • Investigate deep eutectic solvents for selective extraction of lignin and total replacement for kraft pulping | Energy intensity reduction, solvent recovery, fiber strength | High |
| Improvements in kraft pulping | Strength, solvent recovery, lignin isolation and recovery, electrical energy demand for microwave | • Deep eutectic solvents and others for selective extraction of lignin and partial replacement for kraft<br>• Develop pretreatments or additives that reduce the impact of the peeling reaction on yield<br>• Develop strategies or additives that increase the rate of delignification, preserving polysaccharide yield<br>• Identify economical pulping or oxygen delignification catalysts.<br>• Develop cost-effective strategies and/or additives that enable production of higher yield pulps<br>• Revisit microwave pretreatment | Energy intensity reduction, solvent recovery, fiber strength | High |

# Challenges and Barriers – Process Approaches

Reduce energy use **to reduce** carbon emissions arising from paper machine wet end operations (2.07 MMBTU/ton)

| Approach | Barrier | Technical Challenges / R&D Needs | Technology Metrics | Priority |
|---|---|---|---|---|
| Reduce energy use to reduce $CO_2$ emissions from refining paper stock. | Refining is critical operation to achieve performance parameters (strength, etc.) | • Develop more efficient mechanical refining devices, or alternative physical or chemical approaches to fiber development. Approaches could include higher consistency refining, more energy efficient refiners, hybrid conical refiners and refining alternatives e.g., enzymes, chemicals. (refining and drying closely related) | Energy Use | Medium |
| Reduce energy use to reduce $CO_2$ emissions associated with paper forming. | Most approaches can't be easily integrated into existing operations | • Develop techniques to use less water in paper forming such as higher consistency forming and multi-phase forming. | Total Process Energy Use, Water Use, | Medium |

# Project Portfolio (IEDO Cross-cutting – Paper Products)

| Project | Title | Goals | Innovations |
|---|---|---|---|
| 9396<br>Georgia Tech | Advanced Multiphase (MP) forming for enhanced efficiency of drying paper, tissue and other fiber composite products | 1. 8% pt ↑ solids<br>2. 30% ↓ drying energy | • water replaced with high-density (HD) foam in paper forming |
| 9395<br>University of Minnesota | Integrated Radio Frequency and Ultrasonics with Conventional Processes for Efficient Water Removal in Biomaterial Applications | 1. 20-30% ↑ drying rate<br>2. 20-30% ↓ energy<br>3. 25-50% ↓ carbon<br>4. 20-30% ↓ cost | • integrate directed radio frequency (RF) and ultrasonic (US) energy approaches in drying processes |
| 9125<br>Worcester Polytechnic Institute | Novel Energy-Efficient Drying Technologies for Food, Pulp and Paper, and other Energy Intensive Manufacturing Industries | 1. 25-35% ↓ energy | • novel drying technologies<br>• smart sensors<br>• physics-based artificial intelligence methodology |
| 10200<br>UT - Dallas | Non-Evaporative Drying of Porous Materials Using Thermo-Responsive Polymer/Felt Composites | 1. 20% pt ↑ solids<br>2. 30% ↓ drying energy<br>3. 25% ↓ carbon | • Non-evaporative drying technology using thermo-responsive polymer/felt composites |

# Project Portfolio (IEDO Cross-cutting – Wood Products)

| Project | Title | Goals | Innovations |
|---|---|---|---|
| 10201<br>Texas A&M | Efficient Drying Processes of High-Quality Wood through Intelligent Desiccant Assisted Heat Pump System Innovations | 1. 25-30% ↓ energy<br>2. 40-50% ↓carbon<br>3. 25% ↓ oper. cost | • Material innovations for heat pump application<br>• Artificial Intelligence and Machine Learning |