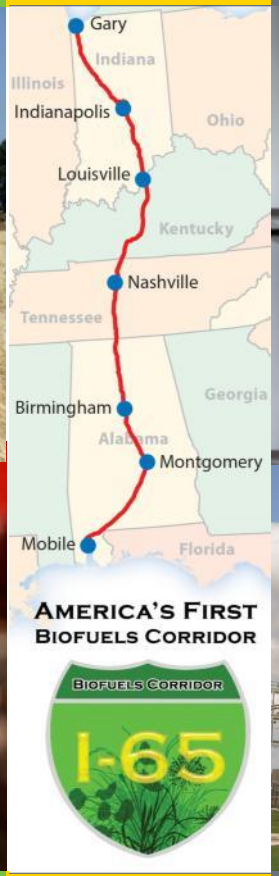
2013 DOE Bioenergy Technologies Office (BETO) Project Peer Review

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



IEA Task 34 Fast Pyrolysis

6.3.2.25

Technology Area Review: Bio-oil

May 21, 2013

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Organization: PNNL

This presentation does not contain any proprietary, confidential, or otherwise restricted information

Goal/Objective Statement

- The ultimate objective of IEA Bioenergy Task 34 is to promote commercialization of economical biomass fast pyrolysis for the production of refinery feedstock and fuel oil with subsequent production of transportation fuels and chemicals

M 6.17 Validate bio-oil production to stable intermediate

- In support of the task, PNNL contributes input on fast pyrolysis developments across the U.S. and in return learns of the work in the other participating countries
- The task undertakes several activities to address barriers to commercialization for fast pyrolysis and PNNL provides laboratory support to those activities and contributes to the information dissemination activities

Quad Chart Overview

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Timeline

- Project start date: 10/1/2008
- Project end date: 9/30/2015
- 64 Percent complete

Budget (DOE & cost share)

- Total project funding $295K + $564K
- Funding received in FY 2011 $20K + $90K (including $20K U.S.)
- Funding received in FY 2012 $20K + $94.5K (including $20K U.S.)
- Funding anticipated for FY 2013 $25K + $99K (including $20K U.S.)

Barriers

- Barriers addressed
  - Tt-E. Pyrolysis of Biomass and Bio-oil Stabilization
  - Dt-B. Codes, Standards and Approval for Use
  - Mm-C. Insufficient or Inconsistent Regulations and Standards

Partners & Roles

- IEA Bioenergy Agreement through Task 34
- Task participants including Ensyn, VTT, BTG and their collaborators

Project Overview

- IEA Bioenergy Agreement
  - DOE is signatory for U.S.
  - U.S. participates in 7 tasks
  - U.S. leads Task 34 on Pyrolysis
- Task participants have included Finland, Germany, United Kingdom, The Netherlands, Canada and Australia
- The task identifies barriers to commercialization of fast pyrolysis of biomass that can be addressed within the task framework
  - Information exchange
  - Standards and analytical methods development

Priority Topics for Task 34

2010-2012 Triennium
Norms and standards
Analysis – methods, comparison, new developments, protocols
Country reports updates/Review of State of the Art
Fuels and chemicals from pyrolysis

- Work scope determined by participating countries
- Tasks undertaken through support from participating countries
- Task progress is monitored by IEA Bioenergy Executive Committee

(View the PowerPoint "Notes" page for additional information)

Norms and Standards

- ASTM standard for fast pyrolysis bio-oil as a burner fuel. (2009)
- First ASTM bio-oil analysis standard method Solids Content in bio-oil by Filtration. (2010)
- Draft mandate was developed for CEN for specifying a number of grades of bio-oil. (2011)
- Draft mandate was used to develop a revised bio-oil standard including a 2nd grade of bio-oil. (2012)
- A definition of bio-oil for a new CAS number. (2010)
- A seminar was presented on the transportation standards and definitions relevant to bio-oil. (2010)
- Testing for sustained combustion as alternative to flash point. Effort to replace flash point testing from standards is now underway led by the task members
- BIOTOX project data was forwarded to toxicity experts working on REACH
- Conclusions relevant to fast pyrolysis bio-oils were presented in a paper dealing with guidelines for transportation of fast pyrolysis bio-oils in Energy & Fuels
- A continuing effort in the new triennium will be the issuance of a new MSDS for bio-oil which will address the several points of confusion

(View the PowerPoint "Notes" page for additional information)

2 - Technical Accomplishments / Progress / Results (cont'd)

Analysis – methods, comparison, new developments, protocols

- Round robin on lignin fast pyrolysis results were published in 2010 in the *Journal of Analytical and Applied Pyrolysis*
- Round robin to compare viscosity results and its measurement in accelerated aging test
  - Participants in the round robin were 15 laboratories in the five participating countries
  - 2 bio-oils distributed in 2011with the results received and documented
  - Published in *Energy & Fuels*
  - Further evaluation of the repeatability of the accelerated aging test by 10 day test.
  - Bio-oil stored for year's time at 3 temperatures to evaluate the effect on the aging of the bio-oil and the resulting viscosity increase.
  - Published in *Energy & Fuels*
- Additional discussions were held on components that are potential problems for bio-oil utilization
  - Key impact on bio-oil utilization
  - Sulfur analysis was considered in detail with the range of analytical methods reviewed
  - Other trace components such chlorine and phosphorus were also considered

(View the PowerPoint "Notes" page for additional information)

Country reports updates/Review of State of the Art

- Presentation of country reports from the participants was a routine part of the agenda for each task meeting
- These country reports are also the basis for the country reports posted on the task website

- A state-of-the-art of fast pyrolysis in the participating countries was drafted into a common format for the journal publication
- The manuscript has been published, Meier, D.; van de Beld, B.; Bridgwater, A.V.; Elliott, D.C.; Oasmaa, A.; Preto, F. "State-of-the-Art of Fast Pyrolysis in IEA Bioenergy Member Countries." *Renewable and Sustainable Energy Reviews*, **20**, *2013*, 619-641.

Fuels and chemicals from pyrolysis

- Collaboration with IEA Bioenergy Task 42 on Biorefineries
- Outgrowth of the previous triennium the interest in fast pyrolysis of lignin continued
- Research ongoing at ECN in the Netherlands
- Direct participation of Paul de Wild, the PI at ECN, continued his interaction with Task 34 by providing reports on his research in lignin pyrolysis and his investigations into biorefineries based on fast pyrolysis
- This work was published as his Ph.D. thesis from Groningen University in 2011

2 - Technical Accomplishments / Progress / Results (cont'd)

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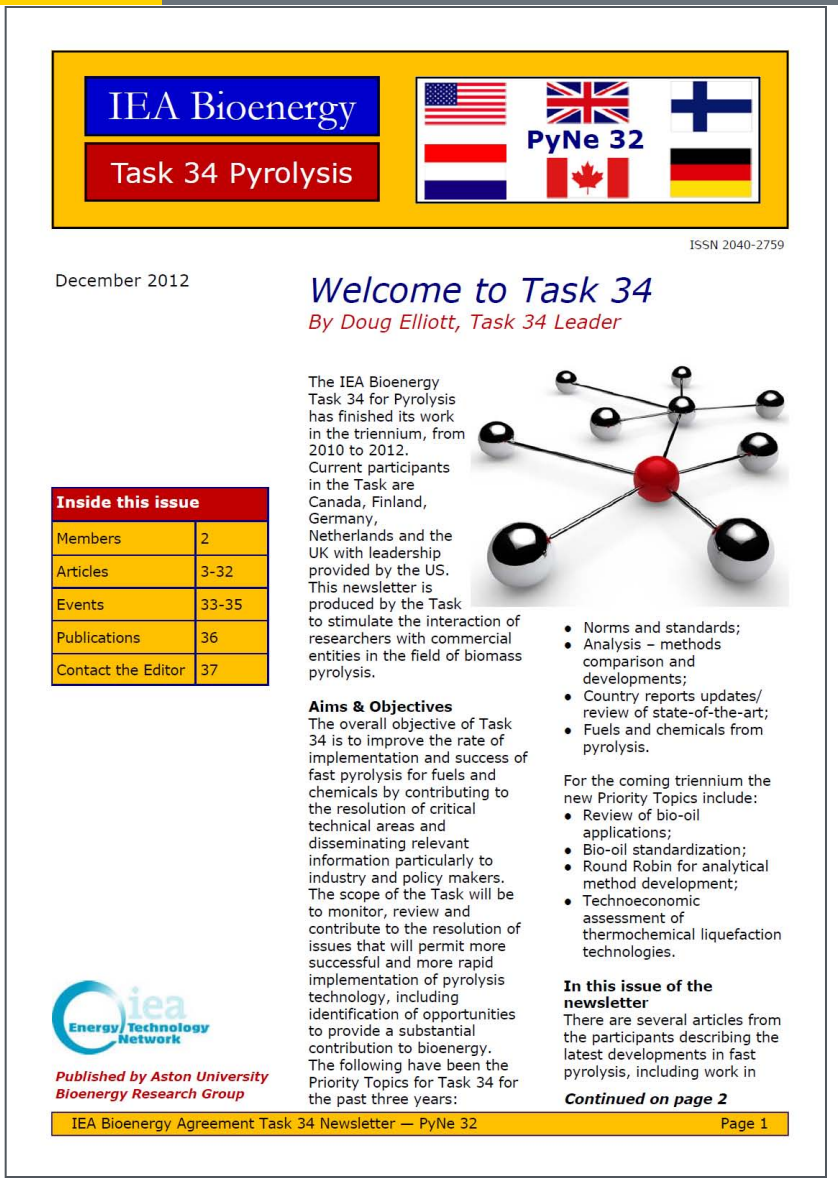
- Continuation and updating of task internet site
- Two task meetings per year
- Two issues per year of the task newsletter
  - prepared with input from participants in each of the countries
  - published electronically by posting to the website

http://www.pyne.co.uk/



IEA Bioenergy

Task 34 Pyrolysis

PyNe 32

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December 2012

Welcome to Task 34

By Doug Elliott, Task 34 Leader

Inside this issue

The IEA Bioenergy Task 34 for Pyrolysis has finished its work in the triennium, from 2010 to 2012. Current participants in the Task are Canada, Finland, Germany, Netherlands and the UK with leadership provided by the US. This newsletter is produced by the Task to stimulate the interaction of researchers with commercial entities in the field of biomass pyrolysis.

Aims & Objectives

The overall objective of Task 34 is to improve the rate of implementation and success of fast pyrolysis for fuels and chemicals by contributing to the resolution of critical technical areas and disseminating relevant information particularly to industry and policy makers. The scope of the Task will be to monitor, review and contribute to the resolution of issues that will permit more successful and more rapid implementation of pyrolysis technology, including identification of opportunities to provide a substantial contribution to bioenergy. The following have been the Priority Topics for Task 34 for the past three years:

- Norms and standards;
- Analysis – methods comparison and developments;
- Country reports updates/ review of state-of-the-art;
- Fuels and chemicals from pyrolysis.

For the coming triennium the new Priority Topics include:

- Review of bio-oil applications;
- Bio-oil standardization;
- Round Robin for analytical method development;
- Technoeconomic assessment of thermochemical liquefaction technologies.

In this issue of the newsletter

There are several articles from the participants describing the latest developments in fast pyrolysis, including work in

Continued on page 2

iea Energy Technology Network

Published by Aston University Bioenergy Research Group

3 - Relevance

- The project identifies barriers to commercialization of fast pyrolysis of biomass and develops and executes a program of collaborative research to provide solutions
- The participation of industrial partners in the task activities validates to utility of the effort and guides the scope of work
- The inclusion of the countries which are leaders in the technology development insures leading edge R&D
- The return on investment is high based on the large cost share involved in the project

Progress in the IEA Bioenergy Task 34 on Pyrolysis

Fast pyrolysis of biomass is a high efficiency method of liquid fuel production. The reason why fast pyrolysis bio-oil may be interesting is that it is the cheapest liquid bio-fuel, due to a relatively simple production process. Moreover, fast pyrolysis can process lignocelluloses without competition to the food chain.

TASK 34 PRIORITY TOPICS

- Norms and standards for Bio-oil utilization
- Country reports updates/Review of State of the Art
- Analysis of bio-oil – methods, comparison, new developments
- Fuels and chemicals from pyrolysis

NORMS AND STANDARDS

CAS # defined and issued #1207435-39-9

"Liquid condensate recovered by thermal treatment of lignocellulosic biomass at short hot vapor residence time (typically less than about 5 seconds) typically at between 450-600°C at near atmospheric pressure or below, in the absence of oxygen, using small (typically less than 5 mm) dry (typically less than 10% water) biomass particles.

A number of engineered systems have been used to effect high heat transfer into the biomass particle and quick quenching of the vapor product, usually after removal of solid byproduct "char", to recover a single phase liquid product.

Bio-oil is a complex mixture of, for the most part, oxygenated hydrocarbon fragments derived from the biopolymer structures. It typically contains 15-30% water. Common organic components include acetic acid, methanol, aldehydes and ketones, cyclopentenones, furans, alkyl-phenols, alkyl-methoxy-phenols, anhydrosugars, and oligomeric sugars and water-insoluble lignin-derived compounds. Nitrogen- and sulfur-containing compounds are also sometimes found depending on the biomass source."

Support to ASTM, CEN and REACH

- ASTM – D-7544 Specification for Pyrolysis Liquid Biofuel
- ASTM – D-7579 Standard Test Method for Pyrolysis Solids Content in Pyrolysis Liquids by Filtration of Solids in Methanol
- CEN/TC 19 – Draft Mandate for pyrolysis oil
- REACH – SIEF definition and data input

ANALYSIS OF BIO-OIL

Round Robin

- 15 laboratories from five participating countries
- 2 bio-oils—filtered and unfiltered
- Viscosity measurement and Accelerated thermal aging test
- Elliott, D.C.; et al. Results of the IEA Round Robin on Viscosity and Stability of Fast Pyrolysis Bio-oils. *Energy & Fuel* **26**, 3769-3776 **2012**.

FUELS AND CHEMICALS

Guidelines for Transportation, Handling and Use of Fast Pyrolysis Bio-oil

- Flammability—flash point and sustained combustibility
- Toxicity—acute, mutagenicity, ecotoxicology
- Transportation Guidelines
- Quality Control and Quality Assurance
- Oasmaa, A.; et al. Guidelines for Transportation, Handling, and Use of Fast Pyrolysis Bio-Oil. Part 1 – Flammability and Toxicity. *Energy & Fuels*, **26**, 3864-3873, **2012**.

STATE OF THE ART REVIEW

- Twice yearly updates on the website
- SOTA journal article—biomass pyrolysis in the participating countries
- Meier, D.; et al. State-of-the-art of fast pyrolysis in the IEA Bioenergy member countries. Submitted to Renewable & Sustainable Energy Reviews

NEWSLETTER

Published electronically twice yearly

WEBSITE

http://www.pyne.co.uk/

ACKNOWLEDGEMENTS

- Natural Resources Canada
- Finnish Funding Agency for Technology and Innovation (TEKES)
- Federal Ministry of Food, Agriculture and Consumer Protection–Germany
- UK Department of Energy and Climate Change
- US Department of Energy
- NL Agency–Netherlands

Anja Oasmaa | Dietrich Meier | Doug Elliott | Tony Bridgwater | Fernando Preto | Bert van de Beld

4 - Critical Success Factors

- Strong connection to industrial leaders in bio-oil production
  - Stefan Muller of Ensyn
    - 4 new plants in development , operating demonstration plant, several smaller plants in operation for chemical food flavoring products in operation since the 1990s
  - Anja Oasmaa from VTT in Finland (consortium of Metso, UPM, Fortum, and VTT)
    - Building a commercial biomass fast pyrolysis plants, operating a scaled-up demonstration plant
  - Bert Van de Beld from BTG
    - To build a fast pyrolysis plant in partnership with Akzo and others

- The task works with and through these participants to address the commercialization barriers
  - The task supported the development of the ASTM standards for bio-oil
    - The initial version from 2009
    - Revised version from 2012
  - Helped develop the mandate that was presented to CEN to initiate the standards writing process in Europe
  - The Task is providing continuing input to the REACH registration process for bio-oil which is currently underway in Europe
  - The task members wrote the description of bio-oil which provided the basis for the CAS number which issued in 2010 and now applies to that chemical composition

5. Future Work

Priority Topics for Task 34

2013-2015 Triennium

- Review of bio-oil applications
- Bio-oil standardization
- Round robin for analytical methods validation
- TEA of thermochemical liquefaction technologies
- Collaboration with Tasks 32, 33, 38, 39, and 42

Future work

ML or DL or Go/No Go	Description	FY13 Q3	FY13 Q4	FY14 Q1	FY14 Q2	FY14 Q3	FY14 Q4	FY15 Q1	FY15 Q2	FY15 Q3	FY15 Q4
A.2.ML.1	Attend Task meeting		■								
A.2.ML.2	Attend Task meeting					■					
A.2.ML.3	Attend Task meeting									■	
A.2.GN.1	propose for new triennium							■		■	
A.2.DL.1	Provide USA developments for IEA Task 34 website		■								
A.2.DL.2	Provide USA developments for IEA Task 34 website						■				
A.2.DL.3	Provide USA developments for IEA Task 34 website										■

Summary

- Task 34 is a key resource for commercialization of fast pyrolysis of biomass:
  - Maintains a website with technical information, key contacts, and news items
  - Prepares and distributes a newsletter twice annually
  - Organizes, conducts and evaluates round robin assessment of important bio-oil analytical methods
  - Provides technical input to standards development efforts in Europe and North America

- This project was presented at the 2011 Platform Review, as part of the CORE Pyrolysis project

Additional Slides

Responses to Previous Reviewers' Comments

2011 reviewer comments

(reviewed as an element in CORE Pyrolysis project)

- Project Approach
  - "It would be useful to develop 'standards', e.g., ASTM standards for bio-oil burner fuels, is a useful first step."
- Technology Transfer and Collaborations
  - "Norms and standards are addressed by the IEA Task 34 work and the work with Finland, Netherlands and Germany which is really good."

- This project has continued these supported efforts.

Publications, Presentations, and Commercialization

- Oasmaa, A.; Elliott, D.C.; Müller, S. "Quality Control in Fast Pyrolysis Bio-Oil Production and Use." *Environmental Progress & Sustainable Energy* **28**(3), *2009*, 404-409.
- Nowakowski, D.J.; Bridgwater, A.V.; Elliott, D.C.; Meier, D.; de Wild, P. "Lignin fast pyrolysis: Results from an international collaboration." *Journal of Analytical and Applied Pyrolysis* **88**, *2010*, 53-72.
- Oasmaa, A.; Kuoppala, E.; Elliott, D.C. "Development of the Basis for an Analytical Protocol for Feeds and Products of Bio-oil Hydrotreatment." *Energy & Fuels*, **26,** *2012*, 2454-2460.
- Oasmaa, A.; Källi, A.; Lindfors, C.; Elliott, D.; Springer, D.; Peacocke, C.; Chiaramonti, D. "Guidelines for Transportation, Handling, and Use of Fast Pyrolysis Bio-Oil. Part 1 – Flammability and Toxicity." *Energy & Fuels*, **26**, *2012*, 3864-3873
- Elliott, D.C.; Oasmaa, A.; Preto, F.; Meier, D.; Bridgwater, A.V. "Results of the IEA Round Robin on Viscosity and Stability of Fast Pyrolysis Bio-oils." *Energy & Fuel* **26**, *2012*, 3769-3776
- Elliott, D.C.; Oasmaa, A.; Meier, D.; Preto, F.; Bridgwater, A.V. "Results of the IEA Round Robin on Viscosity and Aging of Fast Pyrolysis Bio-oils: Long-Term Tests and Repeatability." *Energy & Fuels* **26**, *2012,* 7362-7366

- Commercialization efforts supported by the task
  - VTT (part of the Fortum/Metso/UPM commercialization group in Finland) has been involved in all the task activities
  - Ensyn has participated in all task meetings
  - BTG has been a member of the task in 2012 and will continue through next triennium