CATALYTIC BIOMASS PYROLYSIS FOR PRODUCING PROMISING LIQUID BIO-FUELS (BIOCAT)

Dr. Angelos Lappas

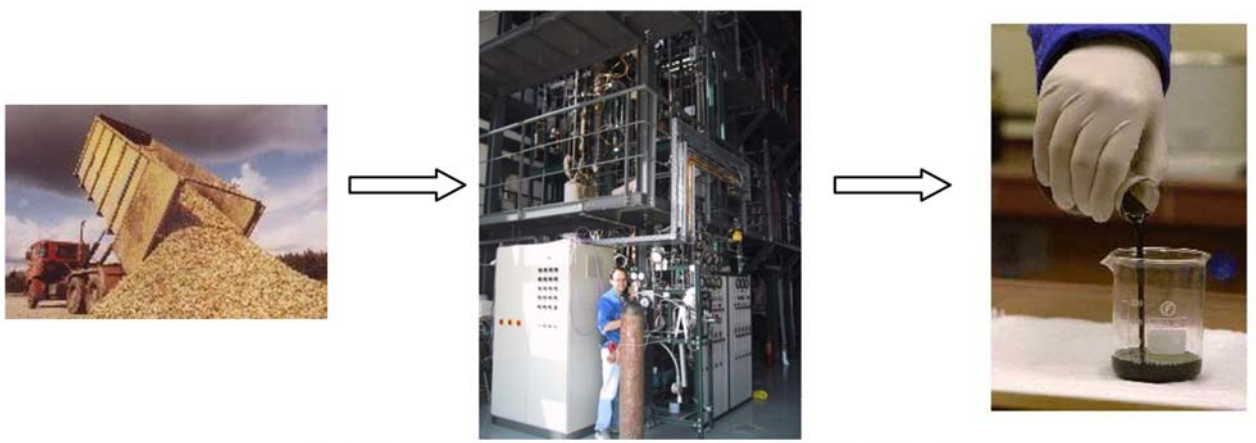
CPERI/CERTH, Thessaloniki, Greece

BIO-ENERGY
ENLARGED PERSPECTIVES

Budapest ,16-17 October 2003

OBJECTIVES

- To develop an efficient technology for the conversion of *biomass* to liquid bio-oil. The technology will be based on *biomass catalytic pyrolysis (BCP)* using new innovative porous catalysts and novel reactors
- To facilitate bio-oil introduction into the European energy market as renewable fuel for diesel engines or as source of high value chemicals

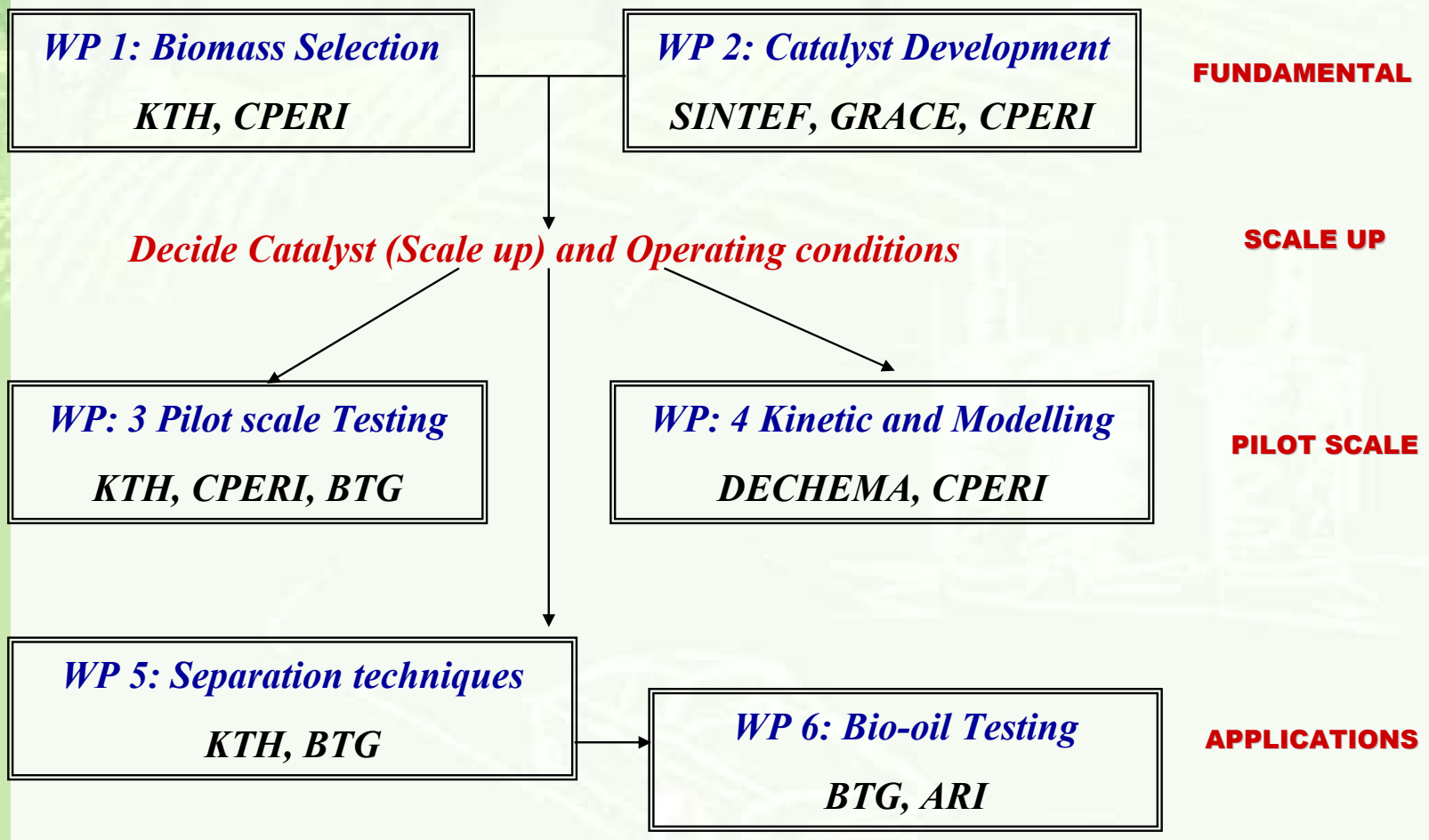


Bio-oil production via biomass catalytic pyrolysis

CHALLENGES/PROBLEM ADDRESSED

- Biomass pyrolysis is a very promising thermochemical process for the production of liquid products
- Large-scale applications are still under consideration because of the high upgrading costs required for bio-liquids
- The production of stable bio-liquids in a single stage catalytic process is being investigated
- Technology: mild cracking reactions in the presence of appropriate catalysts within the pyrolysis process prior bio-oil condensation

WORKPLAN


WP 1: Biomass Selection
KTH, CPERI
WP 2: Catalyst Development
SINTEF, GRACE, CPERI
FUNDAMENTAL
Decide Catalyst (Scale up) and Operating conditions
SCALE UP
WP: 3 Pilot scale Testing
KTH, CPERI, BTG
WP: 4 Kinetic and Modelling
DECHEMA, CPERI
PILOT SCALE
WP 5: Separation techniques
KTH, BTG
WP 6: Bio-oil Testing
BTG, ARI
APPLICATIONS

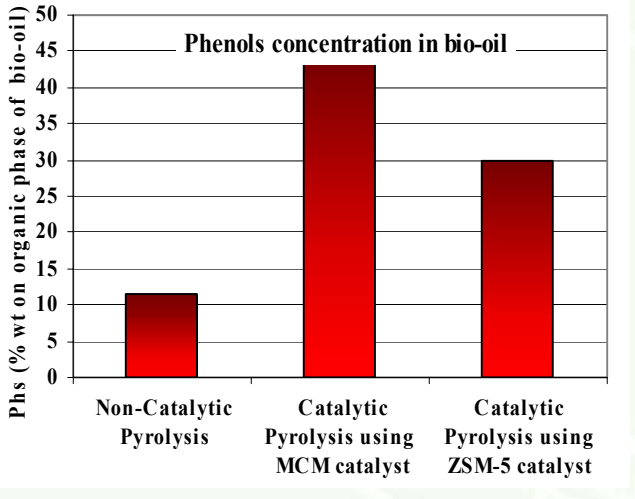
PROGRESS TO DATE (1st HALF)

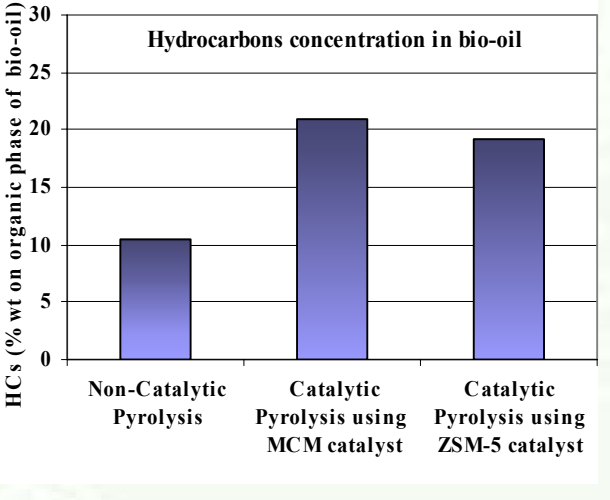
1. Synthesis of innovative catalytic materials for BCP

- **Mesoporous materials:**
  - ✓ *Type: MCM-41, SBA-15*
  - ✓ *Metals*
  - ✓ *Pore size*
  - ✓ *Si/Al ratios*
- **Zeolite ZSM-5:**
  - ✓ *Surface area*
  - ✓ *Si/Al ratio*
- **Zeolite Y (FCC catalyst)**

2. Bench scale evaluation of the new catalysts

- Work in a fixed bed batch reactor using two forestry residues and an energy crop as biomass feed
- The type of catalysts seems to alter the composition of the bio-oil:



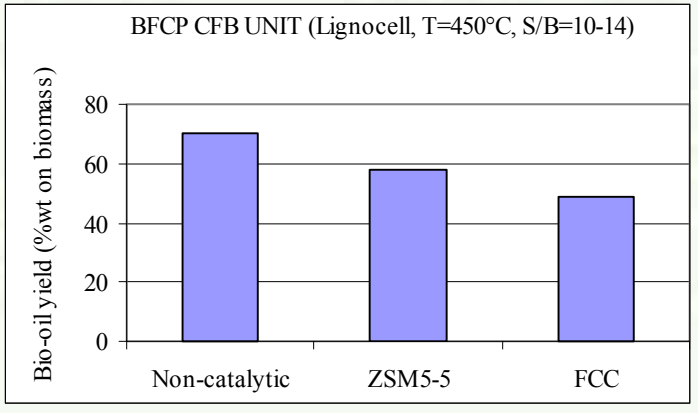


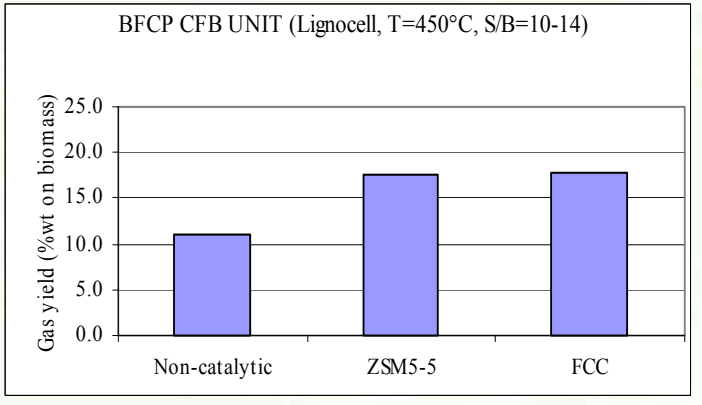
- Best ZSM-5 and MCM-41 selected for scale-up studies

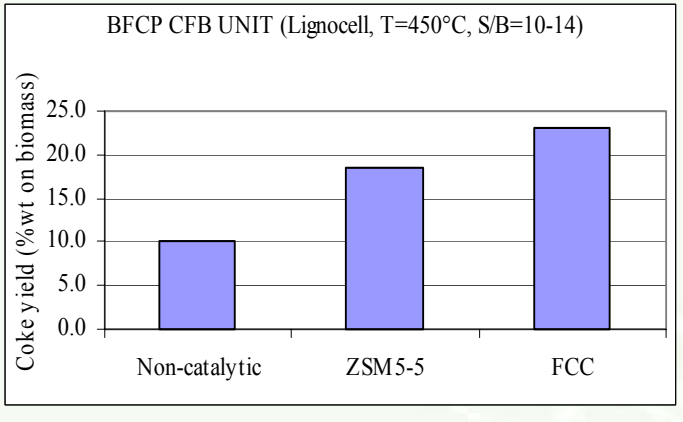
3. Pilot scale evaluation in three reactor technologies

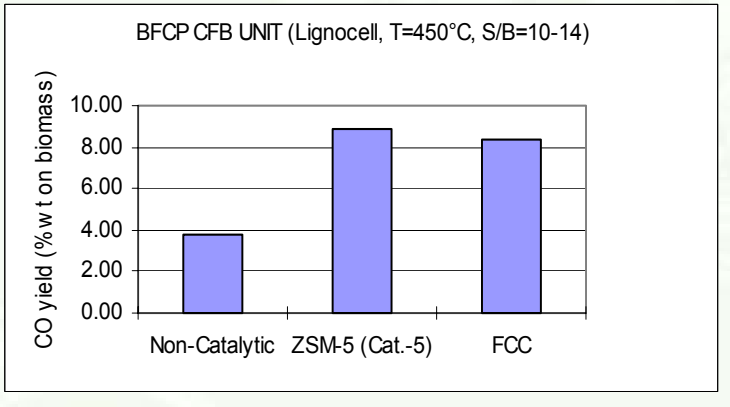
- Pilot plant testing of BCP in:
  - ✓ a fluid bed: 5 gr/min
  - ✓ a circulating fluid bed (CFB): 15 gr/min
  - ✓ a rotating cone (RC) reactor: 200 kg/hr
- Catalytic and non-catalytic tests in the CFB reactor using 3 scaled-up ZSM-5 catalysts
- Full characterization of bio-oil (physicochemical/transport properties, stability tests)

3.1. CFB pilot plant mass balance results



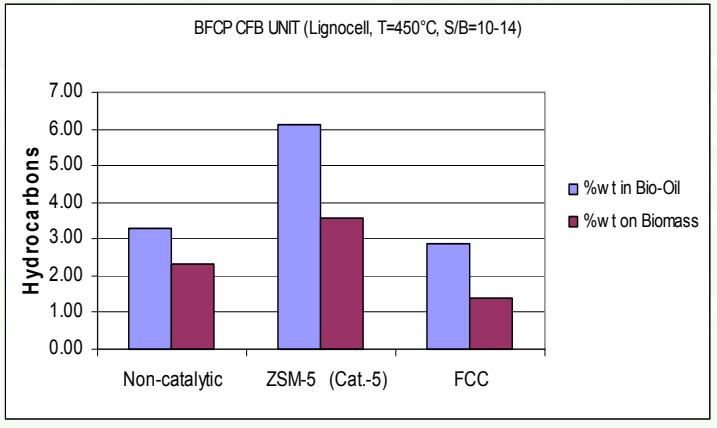


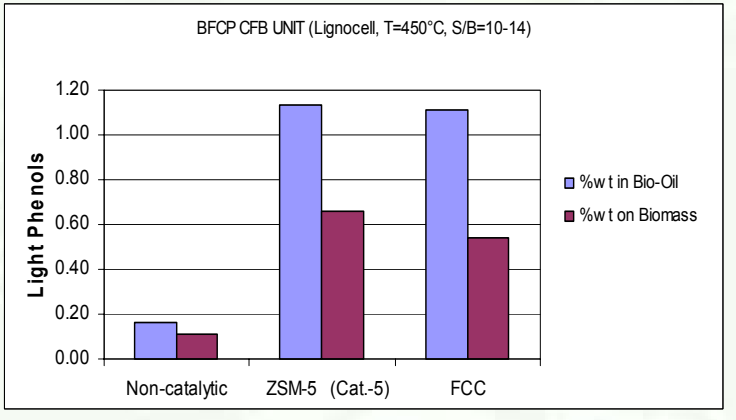


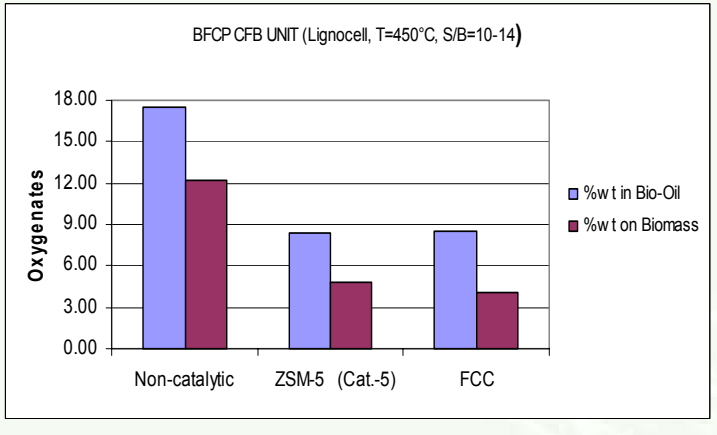


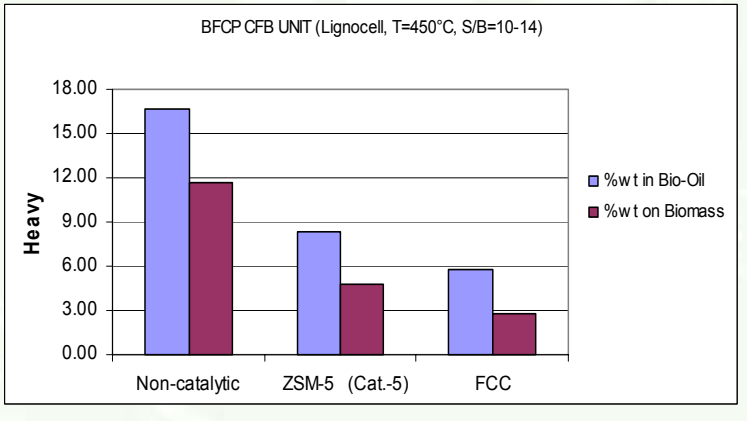
- **BFCP with ZSM-5 decreases liquid yield and increases gas (CO) and coke**

3.2. CFB pilot plant bio-oil quality results







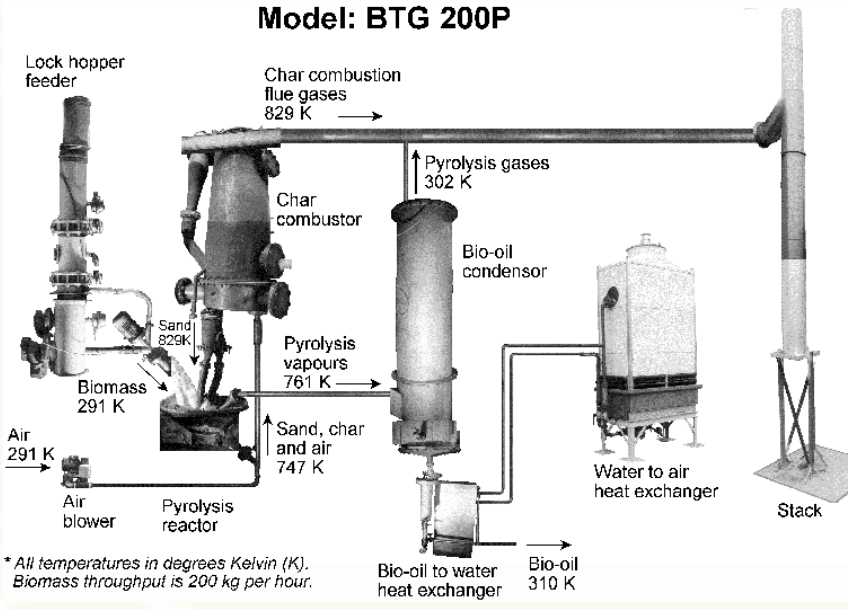


- **BFCP: considerable modifications to the quality of bio-oil**

3.3. Biomass catalytic pyrolysis in RC reactor

- One catalytic pyrolysis run in RC reactor using a FCC catalyst

  - ✓ Operating conditions and catalyst characteristics for BCP tests were established
  - ✓ RC catalytic test in full agreement with CFB reactor results



4. Separation scheme for phenols recovery

- Development of two separation procedures for the extraction of useful chemicals from bio-oil:
  - ✓ Phenols: by liquid-liquid extraction
  - ✓ Carboxylic acids: by esterification of bio-oil by reversible hydroxy binding
- Both methods are under validation. The best will be scaled-up

5. Kinetic and reactor modeling studies

- Estimation of kinetics parameters for BFCP
- Development of a CFD model for the RC reactor
- Modelling of CFB and fluid bed reactor

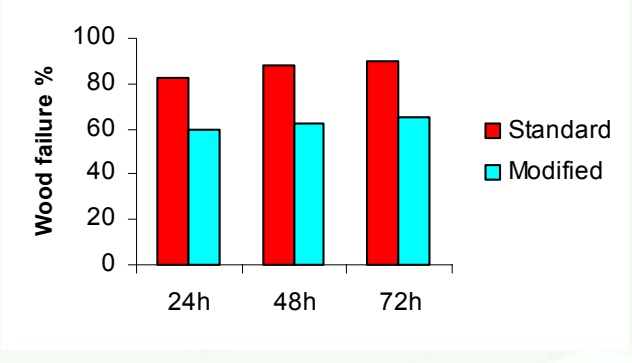
6. Bio-oil testing as fuel in diesel engines

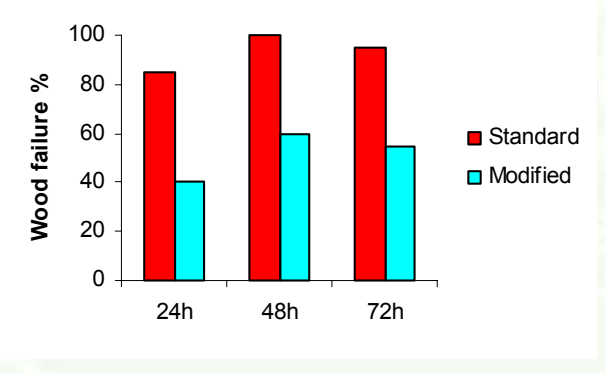
- **Establishing of important bio-oil specifications to run it in diesel engines:**
  - ✓ **Fuel acidity < 2 mg KOH/g**
  - ✓ **Viscosity <100 cP**
  - ✓ **Heating value >12 MJ/Kg**
  - ✓ **High temperature stability**

- **Adaptation of BTG's diesel engines for runing bio-oil:**
  - ✓ **Development of filtration unit**
  - ✓ **Development of novel injectors based on metalloceramic materials**

7. Bio-oil testing in wood adhesives

- Use of bio-oil for production of Phenol-Formaldehyde (PF) resins
- Synthesis of PF resins using non- and catalytic bio-oil
- Substitution levels up to 30% based on new synthesis techniques
- Wood panels made from bio-oil-modified PFs were tested





Bond quality of laboratory plywood produced by the standard method (petroleum phenol) and by catalytic and non-catalytic bio-oil

CONCLUSIONS

- Type of catalyst and type of feedstock affect bio-oil quality for use as fuel or as a source of chemicals
- With the appropriate catalyst more stable bio-oil and with more HC can be produced
- BCP technology can be applied on CFB or RC reactor
- Bio-oil specifications were established for its use as fuel
- Adaptations on diesel engines were also established in BIOCAT for running bio-oil as fuel
- Promising results for application in wood adhesives
- BCP seems to be a very promising process for upgrading bio-oil liquids