Role of thermochemical conversion in biorefineries

J.H.A. Kiel
B.J. Vreugdenhil
M.K. Cieplik
P.J. de Wild

May 2016
ECN-M--16-037

Role of thermochemical conversion in biorefineries

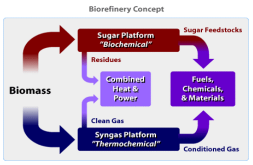
www.ecn.nl
P.O. Box 1
1755 ZG Petten
The Netherlands

Authors

Jaap Kiel
Berend Vreugdenhil
Mariusz Cieplik
Paul de Wild

Corresponding author: kiel@ecn.nl

Introduction



© NREL

ECN focus not only on the classical (NREL) approach:

- (Biochemical) sugar platform versus (thermochemical) syngas platform
- Where dry/wet torrefaction (and pyrolysis) are key enablers for entrained-flow gasification-based syngas production

But also on more advanced thermochemical biorefinery concepts:

- Mild indirect gasification (MILENA) with chemicals co-production
- Pyrolysis-based lignin valorisation

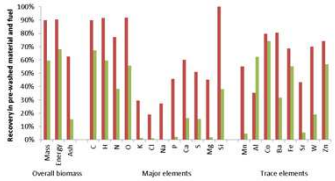
And on the energy island in biorefineries, since this represents a major cost factor (up to 50% of biorefineries CAPEX) and combustion or gasification of many biorefinery residues is not straightforward!

Torrefaction and TORWASH at ECN


Arundo donax, before and after TORWASH, and after subsequent pelletting

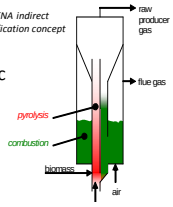
- Pioneering role in dry torrefaction
- TORWASH (= combination of hot washing, wet torrefaction and mechanical drying) allows upgrading of low-quality biomass to white wood pellets quality and beyond
- Elaborate lab-to-pilot-scale torrefaction and TORWASH infrastructure and end-use assessment tools to verify product quality (e.g. durability, water-resistance, grindability, explosivity, biodegradation, leachability, pneumatic feeding behaviour)

Parameter	EN plus A1 pellets	Wood pellets example	Arundo donax untreated	Arundo donax TORWASH
Additives (wt% ar)	none	none	none	none
Moisture (wt% ar)	≤ 10	0.083	variable	0.07
NCV (GJ/ton db)	≥ 16.5	18.6	17.9	20.6
ash (wt% db)	≤ 0.7	0.003	0.023	0.006
Cl (wt% db)	≤ 0.020	0.00012	0.00227	0.00005
K (mg/kg db)		380	4924	116

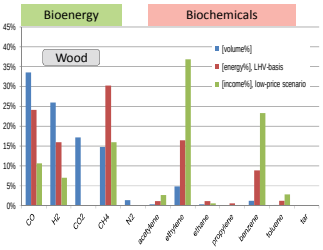


Recovery of mass, energy, ash and elements in pre-washed material (red bars) and TORWASH product (green bars) as a percentage of the amount present in the Arundo donax feedstock

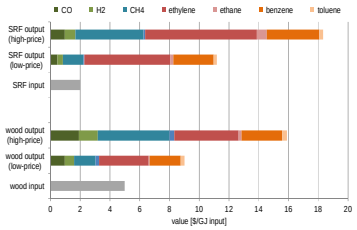
MILENA mild indirect gasification



- Coupled fluidised-bed reactors; air-blown, but medium-calorific N_2-free product gas; 100% carbon conversion
- Low temperature (650-800 °C) – product gas contains valuable "instant chemicals" (typically 60% on energy basis) – allows attractive energy – chemicals co-production schemes



Typical MILENA tar-free product gas composition for woody biomass

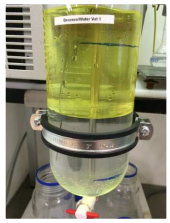


MILENA gasification economics (low-price = based on fossil prices; high-price = 100% premium on syngas, 200% premium on methane, 30% premium on biochemicals)

BTX co-production through selective separation

- Innovative scrubbing technology; may be combined with ECN OLGA tar removal
- For MILENA product gas:
  - >95% selective BTX removal
  - B/T/X = 90/9/1 (typically)
- Simplifies downstream process for SNG production
- Proven on lab-scale for woody and herbaceous biomass and Refuse Derived Fuel (RDF)

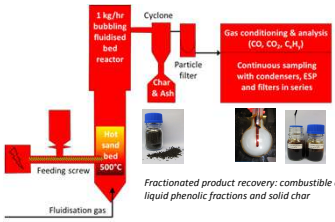




Pyrolysis-based lignin valorisation (LIBRA)

LIBRA involves:

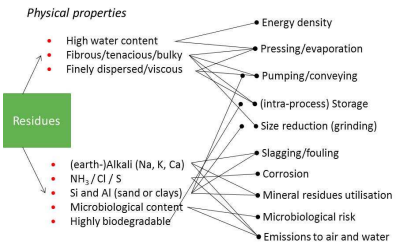
- Conditioning of lignin to prepare it for conversion by pyrolysis
- Feeding the conditioned lignin into a bubbling fluidized bed pyrolyser via appropriate feeding protocols
- Pyrolysis of lignin into gaseous and solid products
- Fractionated product recovery and primary product upgrading (filtration, distillation, etc.)

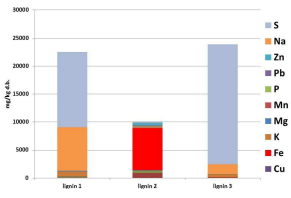


Fractionated product recovery: combustible off-gas, liquid phenolic fractions and solid char

Energy island

- CHP from biorefinery residues (e.g. lignins and humins) – many challenges
- Dedicated combustion and gasification technology required





Lignin: large differences in (inorganics) composition (Beis et al. (2010), Bioresources 5(3), 1408-1424)


Left-to-right: dry lignin, humins and lignin slag

Conclusion

- A closer integration of biochemical and thermochemical processing will lead to superior biorefinery concepts – let's join forces!
- Proper (mild) gasification technologies allow for attractive co-production schemes including chemicals co-production by separation
- The energy island is a major part of the total investment of a biorefinery and biorefinery residues utilisation for CHP requires dedicated technology
- Pyrolysis coupled with fractionated product recovery offers the potential of cost effective production of higher added value chemicals from lignin

More information

Publications: www.ecn.nl/publications
Fuel composition database: www.ecn.nl/phyllis2
BTX: www.bioBTX.com
Milena indirect gasifier: www.milenatechnology.com
TORWASH: www.logistecproject.eu

Acknowledgements

- The financial support from the Netherlands Enterprise Agency (RVO.nl) and the Netherlands Ministry of Economic Affairs is thankfully acknowledged
- The TORWASH research has received funding from the European Union Seventh Framework Programme FP7/2007-2013 under grant agreement n° 311858

ECN
Westerduinweg 3
1755 LE Petten
The Netherlands

P.O. Box 1
1755 LG Petten
The Netherlands

T +31 88 515 4949
F +31 88 515 8338
info@ ecn.nl
www.ecn.nl