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Innovation in gasification technologies

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Luleå University of Technology

- Industry oriented R&D activities in metallurgy, renewable energy, ICT, etc.
- 780 researchers (250 professors)
- Ca. 600 PhD students
- 15 000 BSc/MSc students

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What is gasification?

Gasification in a nutshell

Gasification: $C_xH_yO_z+(0.3\sim0.5)a_sO_2 \rightarrow xCO+(y/2)H_2$

Combustion:

$C_xH_yO_z+a_sO_2 \rightarrow xCO_2+(y/2)H_2O+heat$

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Gasification-based biorefinery

Gasification

Syngas (H_2+CO)

Catalytic conversions

Heat and power generation

Biofuels

Bio-chemicals

Heating /cooling

Electricity

Methanol, natural gas (SNG), FT-diesel, DME, etc.

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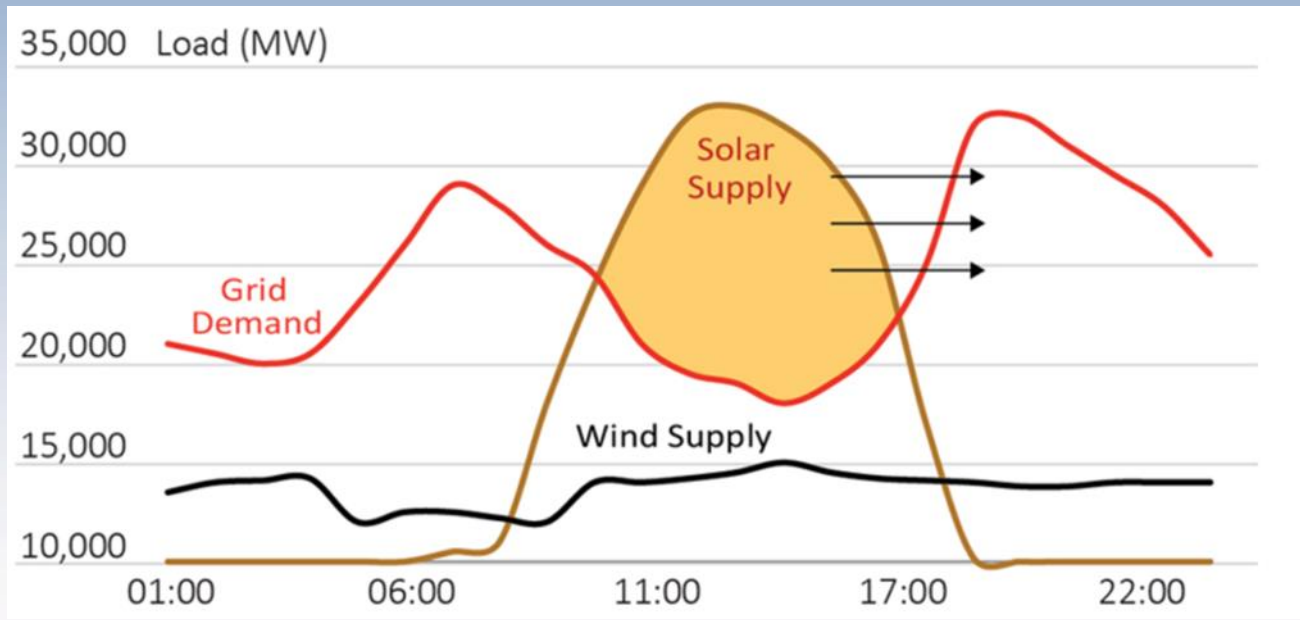
Problems with renewable energy…



https://www.digitaltrends.com/cool-tech/germany-renewable-energy-85-percent/
https://auclimate.wordpress.com/2018/04/17/battery-storage-the-answer-to-renewable-energy-intermittency/

Power-to-fuel?

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Renwable refinery

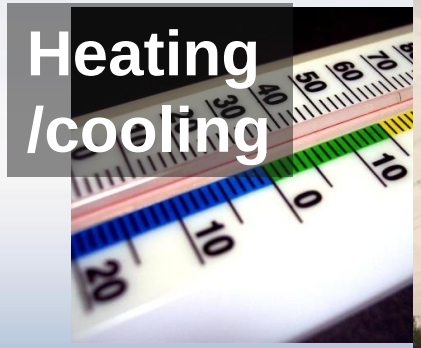
Gasification

O_2

Syngas (H_2+CO)

Catalytic conversions

Heat and power



Methanol, natural gas (SNG), FT-diesel, DME, etc.

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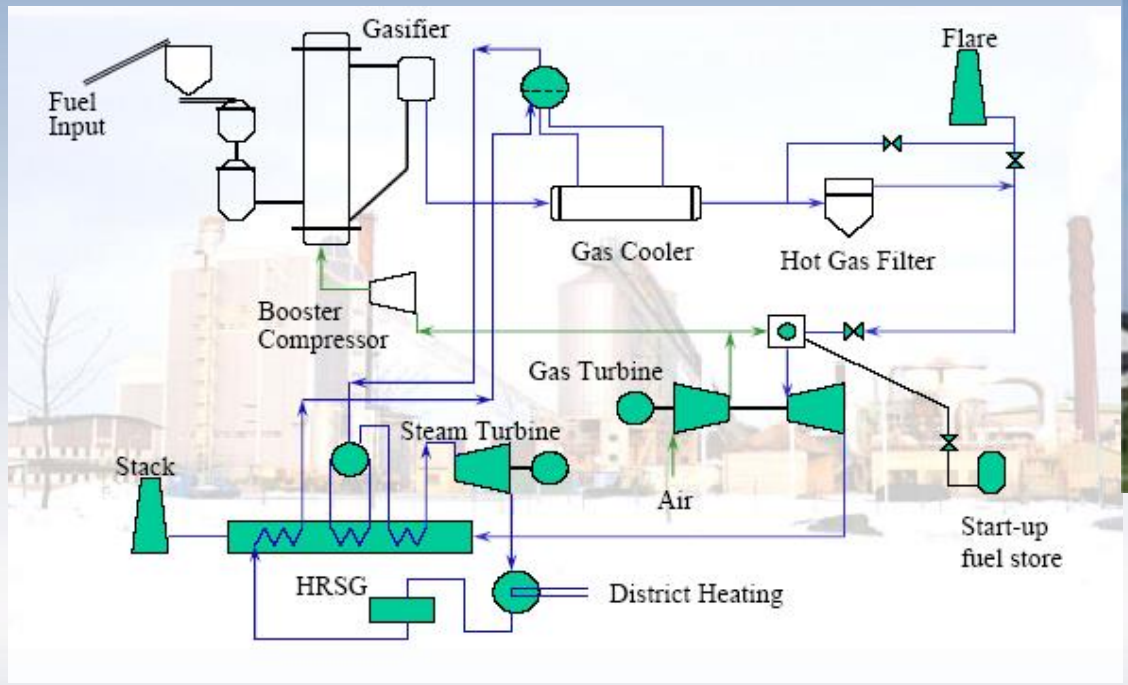
Examples of successful projects

Biomass IGCC plant

Värnamo, Sweden (1991-2010)

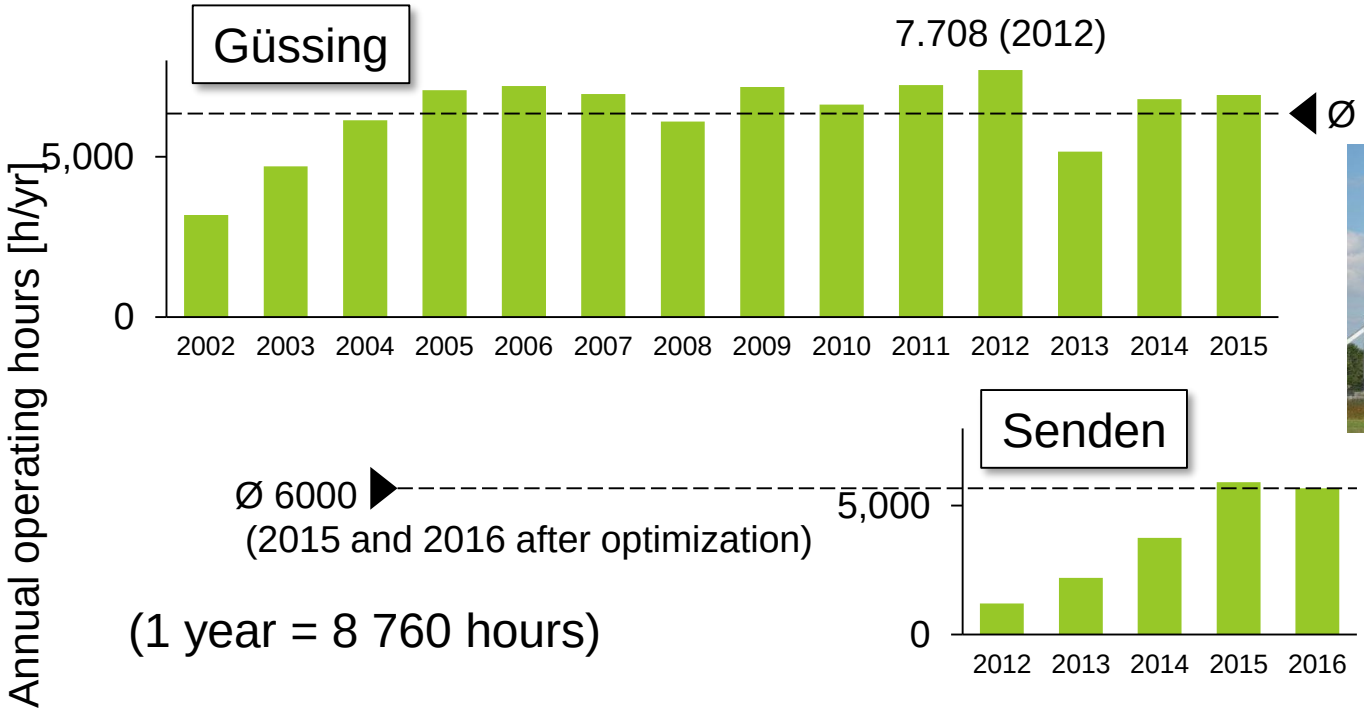
18 MW fuel input
(wood chip, forest residue, straw, RDF)



Electricity: 6 MW
District heating: 9 MW
(overall efficiency: 94%)

1991: Decision for construction
1991-93: Construction
1993-96: Start-up
1996-2000: Demonstration run (gasifier: 8500 hr; CHP: 3500 hr)
2004-2010: CHRISGAS project (EU FP6 & Swedish Energy Agency)

Bio power-heat plant
Güssing, Austria & Senden, Germany

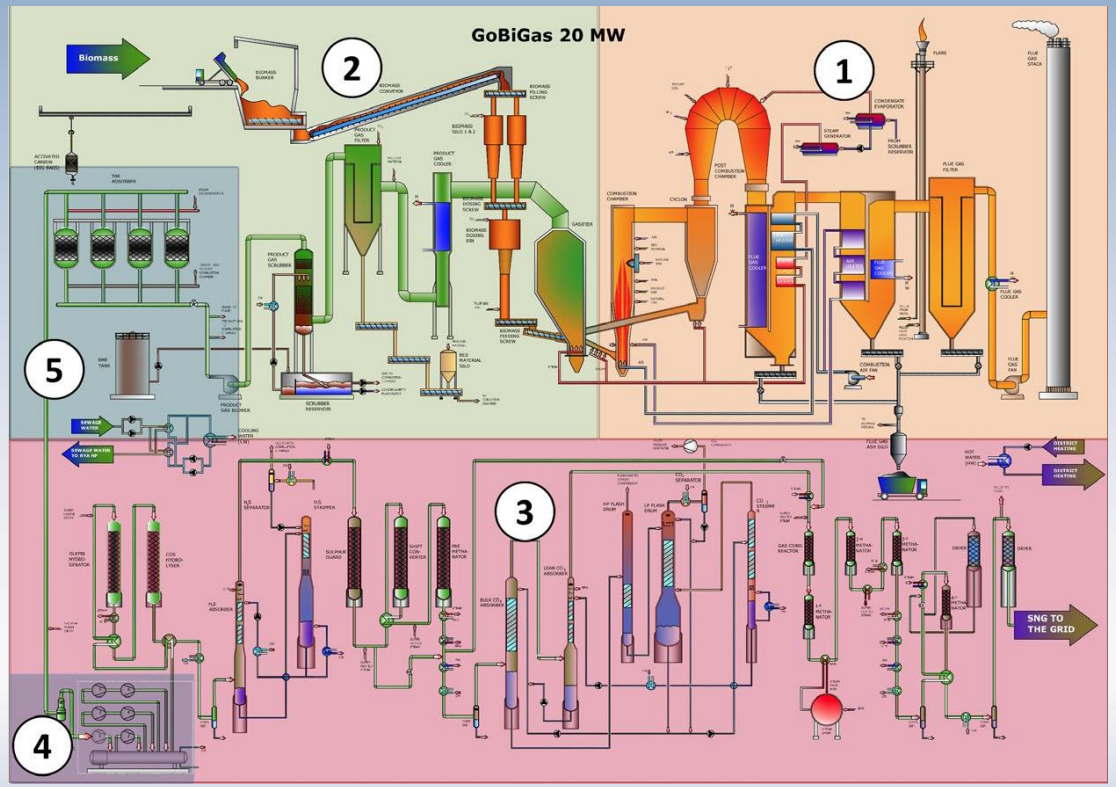


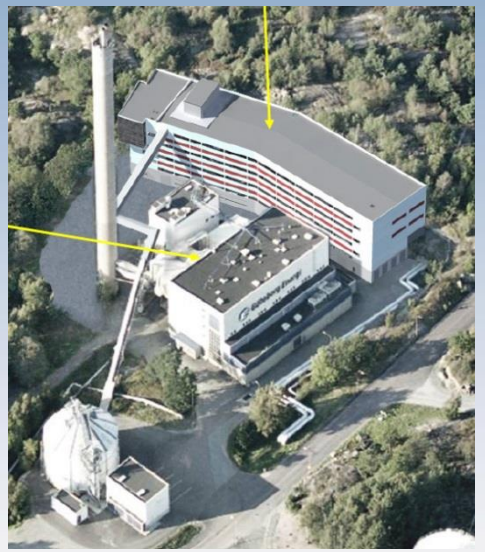
Güssing: 8 MW fuel input→2 MW power + 4.5 MW heat
Senden:14.3MW fuel input→5 MW power + 6.5 MW heat

Bioenergy 2020+: Dr. Matthias Kuba (matthias.kuba@bioenergy2020.eu)

Synthetic natural gas (SNG) plant

GoBiGas, Göteborg, Sweden





2014: ca. 2000 h (clean wood)
2015: ca. 5000 h
2016/17: ca. 3000 h
(low grade fuel)

Fuel: 32 MW→SNG: 20 MW

[H. Thunman et al., Energy Science & Engineering, 2018]
[A. Larsson, IEA task 33 mtg, 2017]

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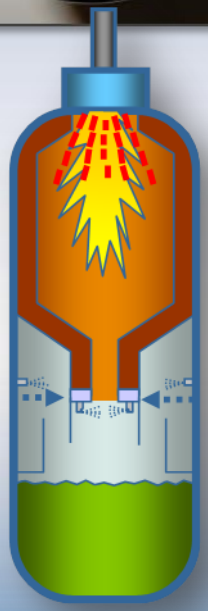
Bio-DME plant
Chemrec-LTU Green Fuel, Sweden



Black liquor (3MW)→methanol, DME

Operation experiences

Gasifier: >28 000 hours (2005-15)
Biofuel/chemical:>12 000 hours (2011-15)
Volvo truck: >1 000 000 km (with DME)

LTU green fuel AB: Mr. Fredrik Granberg (fredrik.granberg@ltu.se)

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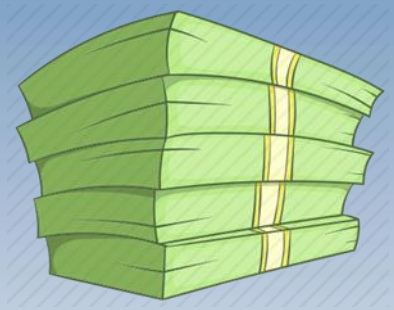
Challenges

Common challenges in gasification



- Economy
- Long startup operation (3-5 years)
  - Feeding issues
  - Tar clogging
  - Ash deposit

Tar?

While a great deal of time and money has been spent on biomass gasification in the last two decades, there are very few truly commercial gasifiers, operating without government support or subsidies, day in, day out, generating useful gas from biomass. *The typical project starts with new ideas, announcements at meetings, construction of the new gasifier. Then it is found that the gas contains 0.1-10% 'tars.' The rest of the time and money is spent trying to solve this problem.* Most of the gasifier projects then quietly disappear. In some cases the cost of cleaning up the experimental site exceeds the cost of the project! Thus 'tars' can be considered the Achilles heel of biomass gasification. (In the gasification of coal, a more mature technology, the 'tars' (benzene, toluene, xylene, coal tar) are useful fuels and chemicals. The oxygenated 'tars' from biomass have only minor use. With current environmental and health concerns, we can no longer afford to relegate 'tars' to the nearest dump or stream.

Tom Reed (1998)

http://www.biomassgasification.net/

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Waste… Opportunity or buzz word?

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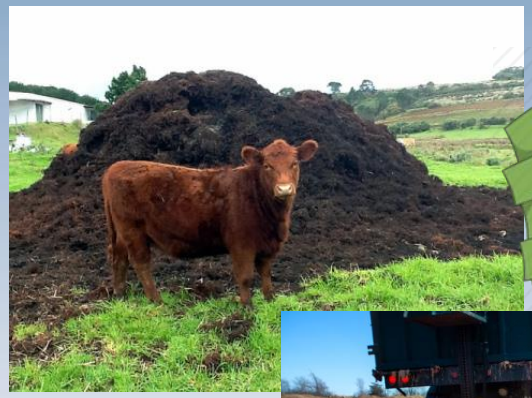
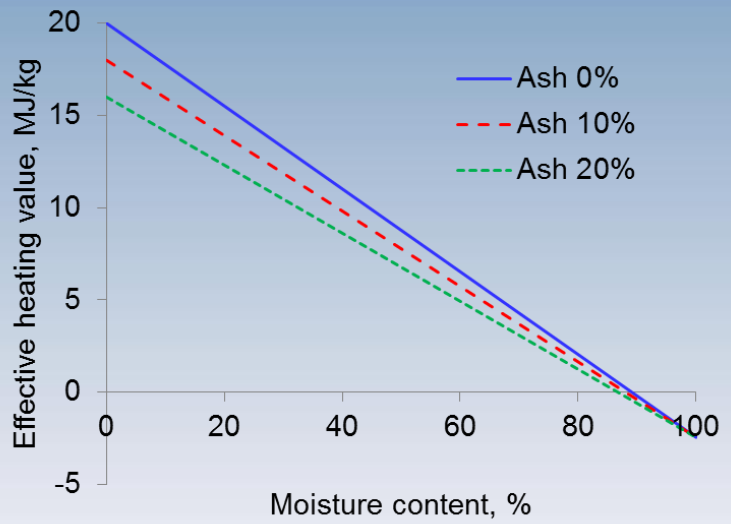
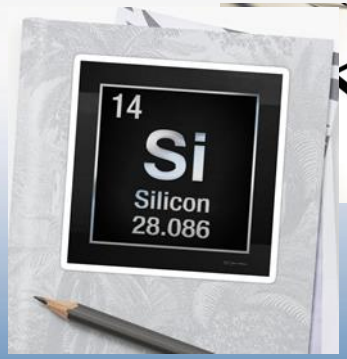
Is waste oppurtunity for gasification?



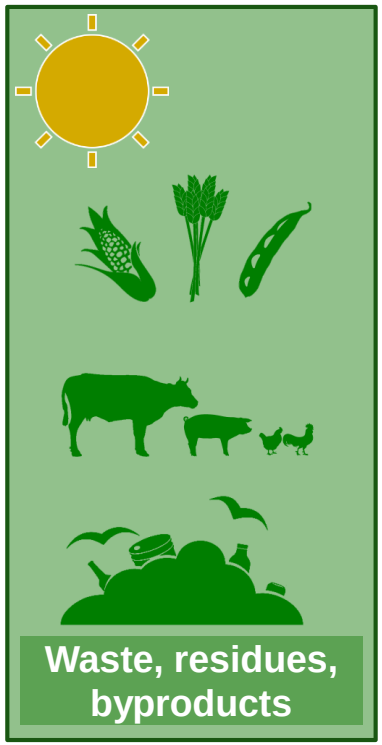


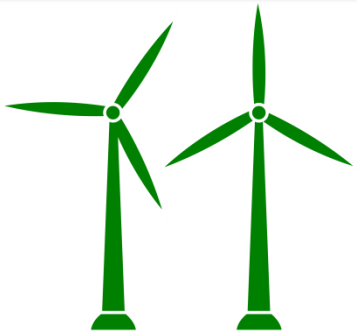


https://phys.org/news/2017-06-food-green-energy.html
https://clearingcustoms.net/2017/04/13/missionaries-ministers-money-and-manure-dont-pile-em-up-or-so-they-say/

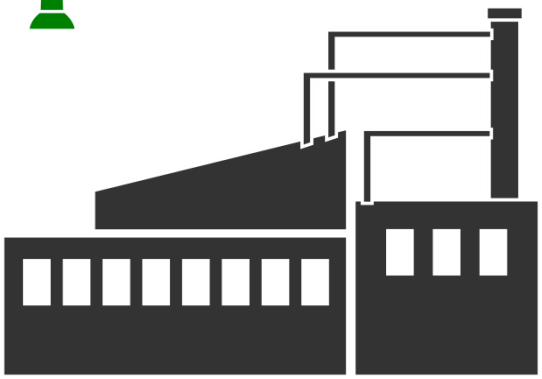
Gasification of biomass and waste

On-going activity (bio-/recycle-industry)
Build-up of a 1 MW pilot plant with complete process chain (Fischer-Tropsch-synthesis, H_2-production, etc.) based on sewage sludge and plastic waste





Optional: Peak-wind energy



Gasification + Synthesis

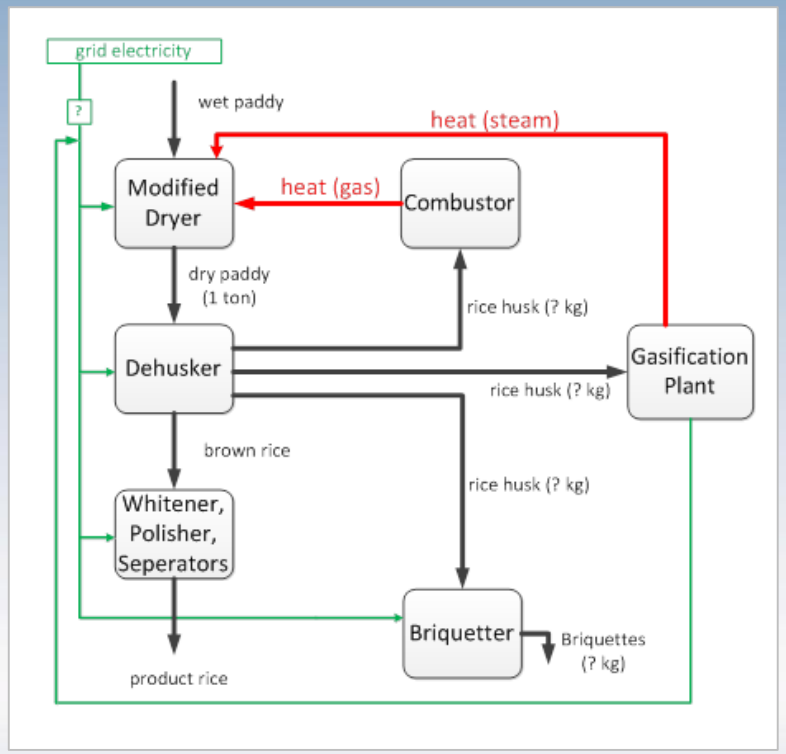
Commercially competitive biorefinery products

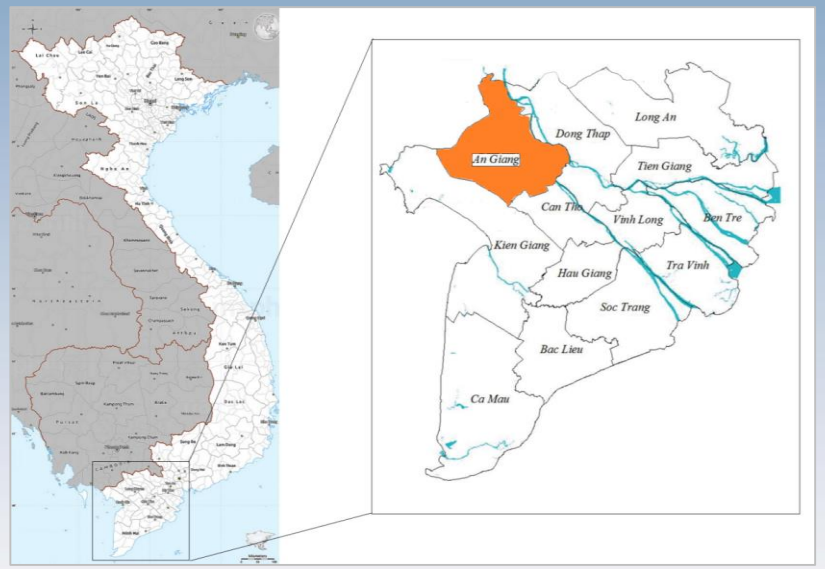
Substances
- Wax
- Kerosene
- Alcohols
- Diesel
- Phosphorus

Gases
- Hydrogen
- Gas - SNG

Bioenergy 2020+: Dr. Matthias Kuba (matthias.kuba@bioenergy2020.eu)

Case study: rice husk for power generation
(Ann Giang province, Vietnam)





- Rice husk waste as fuel.
  - Electricity to be sold.
  - Heat for drying in rice mill.
- Excess husk for briquette.
- Ash may be sold as silicon.

[A. Krüger, MSc thesis, Luleå University of Technology, 2014]

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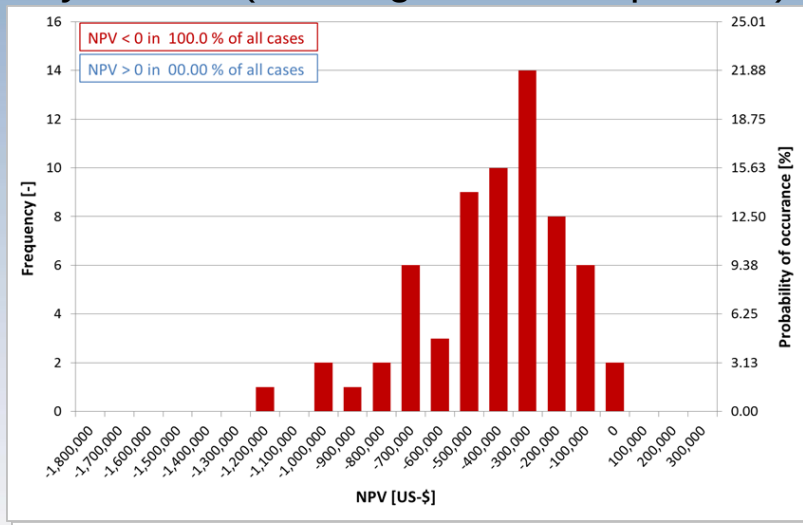
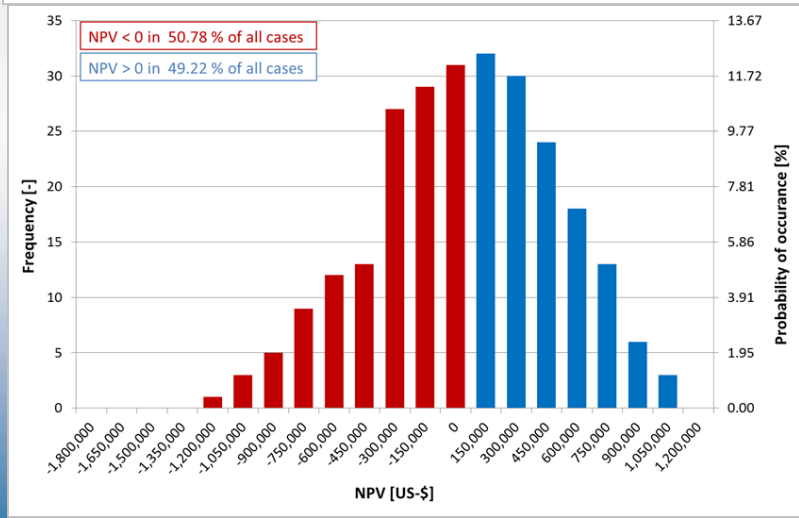
Case study: rice husk for power generation
(Ann Giang province, Vietnam)

Information	Unit	Without ash sales	With ash sales
Investment cost (CAPEX)	US-$	1 536 000	1 536 000
Total revenue	US-$/year	371 574	491 008
Total costs	US-$/year	279 314	281 181
Cost for electricity production	US-$/kWh	0.09	0.09
Operating cash flow	US-$/year	92 260	179 748
NPV	US-$	-746 302	2 550
Spec. NPV	%	-48.6	0.2
IRR	%	-	8.03
Payback time	years	16.6	8.5

Numbers for 480 kWh (el) capacity

Probablity of NPV (red: negative; blue: positive)





[A. Krüger, MSc thesis, Luleå University of Technology, 2014]

Take-home messages (what we know)

- Gasification is flexible (feedstock & products)
- Biomass gasificaiton is a mature technology.
  - Heat and power from <1 MW
  - Chemical/fuel production must be >10 MW
- But, there are challenges…
  - Startup operation (mainly feeding, tar, and ash)
  - Economic performance
- Excess heat and ash must be used/sold to be profitable.
- Waste gives opportunities and challenges.
  - Low (or negative) feedstock price
  - Recovering valuable elements (e.g. P, K, Si, etc.)
  - Low fuel quality (moisture, ash, S, N, etc.)

Take-home messages (suggestions)

- If you are to invest, be prepared.
  - Know your waste!
  - Start-up can be a long shot (3-4 years).
- Cheap energy price requires gov't support.
  - Subsidies for CAPEX and/or low interest loan.
  - "Predictable" price tags for CO_2 (carbon tax, emission trade, green electricity certificates).
- Use competences and knowledge in academia!
  - But, prepare to listen for painful critics and suggestions ☺

Questions?

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