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Energy research Centre of the Netherlands

Ash from combustion of cacao residue for nutrient recycling: a case study

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Co-firing consortium

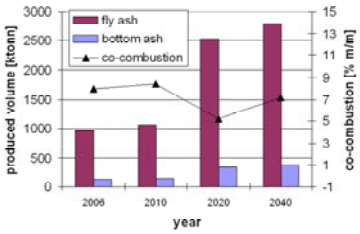
- Consortium of ECN and KEMA on co-firing biomass and coals
- Ash management one of the topics
- Objective: to ensure that issues related to ashes do not inhibit the growth of biomass fuels for energy production
- *Find useful applications for all ashes*
- Recycling is one option

Bulk of solid biomass fuels in NL

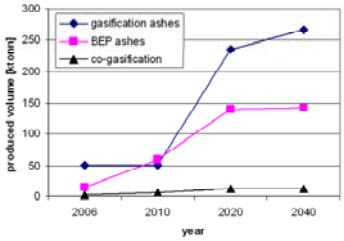
- Co-firing in coal plants
  - > 1,000,000 ton/a clean wood
  - 100% of ashes are utilized
    - bottom ash in road construction
    - fly as in concrete (EN-450)
  - dominated by coal ash → recycling is no option
- Problems with ashes of “pure” biomass plants
  - wood and park waste, almost no agro residues
  - small CHP plants → many small ash volumes of variable quality and quantity (also over time)
  - ashes blended into building products or land filled

Growth of biomass ash volumes in next decades

- Prediction: exponential growth after 2010



co-firing



stand alone

- Development of new utilisation options needed for 150,000 ton of “pure” biomass ashes

Ash recycling and sustainability

- “Is it possible to recycle the biomass ashes produced in the Netherlands?”

- EU and national criteria for sustainable biofuels: *restoring the nutrient balance of the soils*

  → no depletion of nutrients

- Role of biomass ashes?

Nutrient Recycling in Five Cases

- From scenarios major ash volumes selected
- Five cases for further study:
  1. clean wood pellets/chips in FBC
  2. residue from rape seed oil pressing in FBC
  3. cacao shells in FBC
  4. direct co-firing with coal
  5. biomass co-firing in EF gasification

Cacao shells rationale

- Large cacao industry in region Antwerp – Amsterdam – Hamburg
  - cacao shells are a waste product
  - high calorific value, good fuel, clean fuel
  - nutrients mainly P and K
  - currently used in gardening
  - currently fired in mixed biomass

- Combusted in a dedicates plant
  - separate cacao shells ash, and…
  - … ashes returned to the plantations

Utilization of biomass as fertilizer - as old as agriculture

Two scenarios

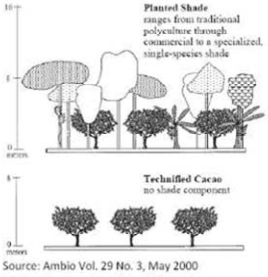
1) Ashes are transported by sea and truck, back to the cacao plantation and replace artificial fertilizer
2) Ashes are transported to a mine in Germany and fertilization is done by means of artificial fertilizer

How much is available in NL?

- Total import in Netherlands (2006):
  - cacao beans: 450,000 ton/a
  - 10% is shell → 45,000 ton/a = 25 MW(th)
- Total ash production
  - ash content of dried cacao shells: 7-9 wt%
  - 80 wt% of ash as useable fly ash in FBC
  - 3000 ton/a recyclable ash
- Composition (calculated)
  - P: 4.2 wt%
  - K: 39 wt%

Cacao case study

- Sustainable plantations use artificial fertilizers and plant cacao trees together with shadow plants
- Ivory Coast exports 1,300,000 ton beans per year; 40% of World production

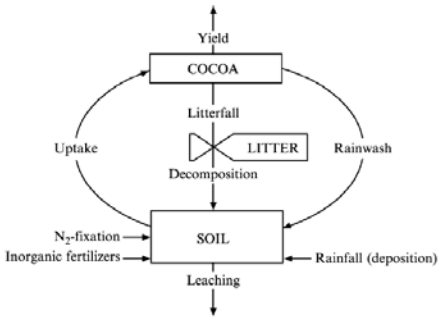


Source: Ambio Vol. 29 No. 3, May 2000

Cacao harvesting

Only beans are shipped, husks and leaves stay at plantation

Nutrient balance of 1 ha plantation



- Productivity: 740 kg dry beans per ha per year
- Residues (husks) already used at plantations
- Amounts of fertilizers needed is not 100% clear from literature: statistical approach

		Nutrient demand	Husks	Natural addition of nutrients	Amount to be added by means of fertilizer/ash
N	kg/hectare	126	13.2	43.3	69.5
P	kg/hectare	26	1.83	0.30	23.9
K	kg/hectare	202	43.1	95	63.9

Fertilizer and ash needed for two scenarios

Scenario 1	Amount to be added by means of fertilizer/ash	Filter ash	To be delivered by fertilizer	Artificial fertilizer	Amount needed of artificial fertilizer
	kg/hectare	kg/hectare	kg/hectare		kg/hectare
N	69.5	0	69.5	urea	298
P	23.9	0.22	23.7	tripelsuperfosfaat (48% P2O5)	112,7
K	63.9	2.05	61.9	potassiumchloride (60% K2O)	124,5
Scenario 2	**Amount to be added by means of fertilizer/ash**	**Filter ash**	**To be delivered by fertilizer**	**Fertilizer**	**Amount needed of artificial fertilizer**
	kg/hectare	kg/hectare	kg/hectare		kg/hectare
N	69.5	--	69,5	urea	298
P	23.9	--	23,9	tripelsuperfosfaat (48% P2O5)	113,8
K	63.9	--	63,9	potassiumchloride (60% K2O)	128,6

Conclusions used in the Environmental Impact Analysis

- Ashes from combustion of cacao shells can replace a small fraction of artificial fertilizers, about 1 wt%
- Impact measured in terms of emission of CO_2, NOx and SO_2
- Ca, Mg and all other (trace) elements are not included in the evaluation
- No social impacts evaluated
- No costs in calculations

Environmental impact ≠ LCA

Process step	Scenario 1 (per hectare)	Scenario 2 (per hectare)
Transportation of ash to port in the Netherlands	5.3 kg ash 100 km	--
Transportation of ash to salt mine in Germany	--	5.3 kg ash 250 km
Transportation of ash to Ivory Coast	5.3 kg ash 6000 km	--
Transportation of ash to cacao plantation	5.3 kg ash 800km	--
Production of fertilizer in Ivory Coast	--	1.1 kg tripelsuperfosfaat 4.1 kg potassiumchloride
Transportation of fertilizer in Ivory Coast	--	5.2 kg fertilizer 800 km

Nearly all process steps are the same, so only the differences are investigated:

- transportation
- fertilizer production

Data from SimaPro and ECLIPSE

Comparison of the two scenarios
in terms of emissions of CO_2, NOx and SO_2

	CO2	NOx	SO2
	gram	gram	gram
Scenario 1	947	18.1	6.9
Scenario 2	2936	19.5	16.5

- Returning ashes to the soils (1) has lowest impact
  - main cause of difference: production of fertilizer
  - transport better in scenario 2
- Fertilizer production outweighs transportation

Sensitivity analysis

- Influence on result:
  - availability of nutrients in ash to cacao plants
  - production of dry beans per hectare
- Small influence on result:
  - transport distance in Ivory Coast
  - thickness of shells
- No influence on result:
  - total nutrient demand of plantation
  - natural NPK input/output in soil
  - recycling of husks for NPK

Conclusions

- Returning ashes from combustion of cacao shells will bring back about 1 wt% of needed fertilizer
- Returning those ashes to the cacao plantation has the lower environmental impact (expressed as emissions of CO_2, NOx and SO_2), mainly due to avoided production of fertilizer
- Third option could be even better:
  - Use ashes as fertilizer in NW-Europe
    - the same lower impact of fertilizer production as in scenario 1
    - low transport impact of scenario 2

Thank you for your attention

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