Life Cycle Analysis of Biochar

Ecobalances of Biochar Production and Utilization

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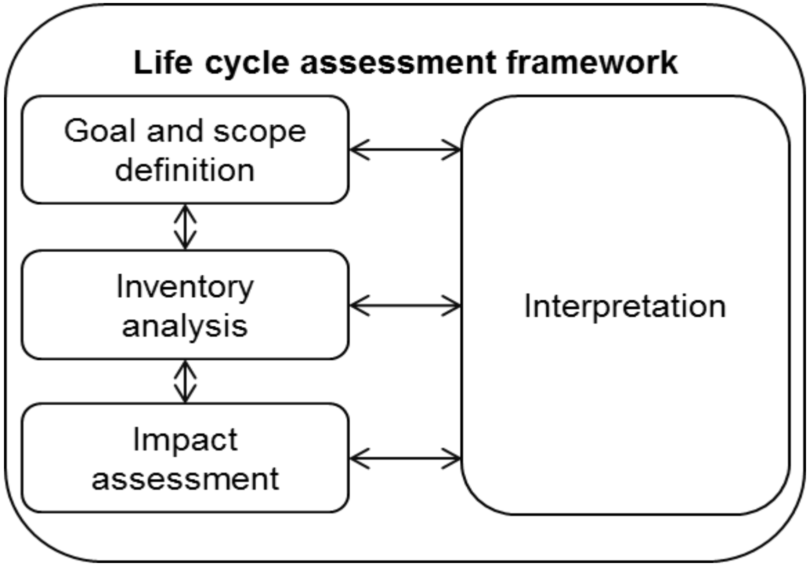
Tuesday, 10th of December 2013

Agenda

- Introduction to Life Cycle Assessment
- Previous Biochar-LCA's
- LCA methodology for Biochar
- The BAPU-Model
- LCA-Results
- Sensitivity analysis
- Conclusion

Life Cycle Assessment



The International Standards Organisation (ISO) produced the ISO 14040 series

It
- provides a loose framework of guidance on how to conduct life cycle assessment;
- is well established in the scientific world, in industry and politics;
- is an approach to quantify the environmental impact of product systems.

Previous LCA-Results

Reference	Substrate	Dry matter	Char yield	GHG-Mitigation		
	[-]	[% kg_{DM}^{-1}]	[% kg_{DM}^{-1}]	[kg CO_{2eq} t_M^{-1}]	[kg CO_{2eq} t_{TS}^{-1}]	[kg CO_{2eq} t_{Kohle}^{-1}]
Gaunt and Lehmann (2008)	Switchgrass	50	8,5	654*	1.307	7.688*
	Miscanthus	50	8,7	930*	1.328	10.685*
Gaunt and Cowie (2009)	Switchgrass	50	38,5	580* / 910*	1.160 / 1.820	-1.506*/ -2.363*
	Straw (Wheat)	80		792* / 1.320*	990 / 1.650	2.057* / 3.428*
Roberts et al. (2010)	Switchgrass	50	29	221*	442	762*
	Rapeseed straw	45		356* / 389*	793 / 864	1.227* / 1.341*
Hammond et al. (2011)	Wood chips	75	33,5	877*	1.170	2.619*
	Short Rotation Coppice	50		565*	1.130	1.687*

* ohne Gewähr, umgerechnet anhand des Trockensubstanzanteils und des Kohleertrags lt. der jeweiligen Studie

Conclusion:

- 221 – 1.320 kg CO_{2eq} t_{FM}^{-1}
- 442 – 1.650 kg CO_{2eq} t_{DM}^{-1}
- 762 – 10.685 kg CO_{2eq} t_{Char}^{-1}

Are these amounts valid for the North Sea Region in general?

Comparability of results

Biomass availability

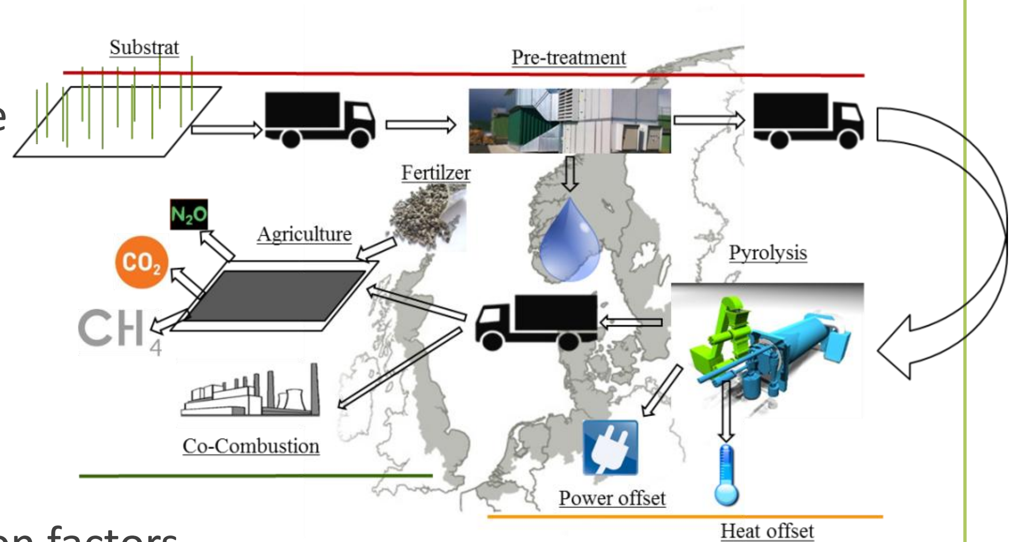
- Regional differences
- Transport distances are important

Biochar production

- State of the art
- Temperature and retention time
- Batch or continuous

Char properties

- Stability
- Carbon content (Heating Value)



Offsets

- Heat and Power
- Specific Greenhouse gas emission factors
- Direct substitution of fossil fuels (Hard coal or natural gas)

Soil characteristics

- Sand, loamy, clay
- Biochar dosis per hectare

Life cycle methodology for Biochar systems

Uncertain Data

→ Improvement of technology and material data

- Relatively new systems
- Only limited applications so far
- Lack of reliable primary data

→ Uncertainty of biochar effects

- Crop growth
- GHG-Emissions
- Duration

Methodological Problems

- Sometimes more influential than uncertain data
- ***Attributional*** or consequential approach
- Counterfactuals
  - Implicit: Offsets of avoided fossil emissions
- Definition of products and allocation between them
  - By heating value of products
- Timescale Issues
  - GWP_{100}

Vision of the model

- **Goal: LCA-Model for the North Sea Region**
- Supply of available biomasses (e.g. amount dependent on competition between sectors)
- Data of commercial pyrolysis units
- Integration of own analyses (e.g. Char properties)

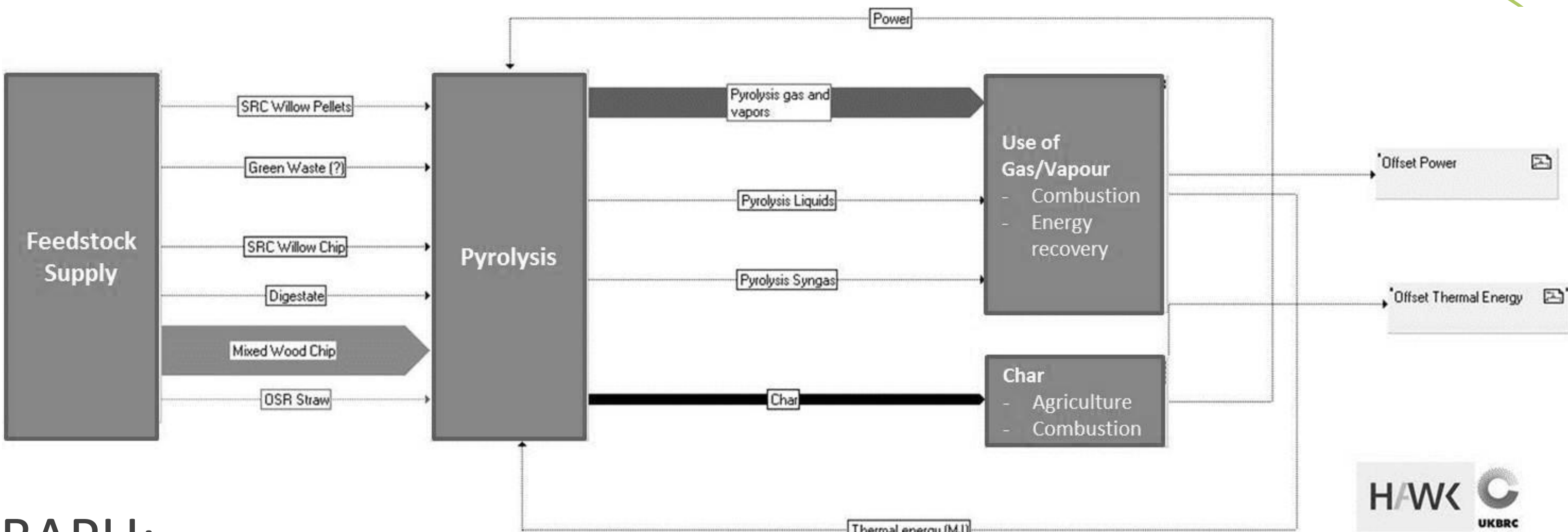
Procedure:

- ISO 14040/44 compliant data sets
- 6 different biomasses
- Visit of several pyrolysis units
- Data sheet for primary data and compilation with literature
- Automatic link between substrate, energy flows and char quality
- Model is applicable to all countries within the North Sea Region

- *Empirically based statement of the greenhouse gas mitigation potential due to biochar utilization in the agricultural or energy sector within the North Sea Region*

The BAPU – Model

- **B**est **a**vailable **P**yrolysis **U**nits -



BAPU:

- 6 substrates (pre-treatment included)
- 3 commercial units + data sheets
- 2 Utilization paths
  - Agriculture
  - Co-Firing
- Model can easily be extended

Considered Substrates

Parameter	Unit	Green Waste	AD Digestate	OSR Straw Pellets	Wood-chips	Willow Pellets	Soft-wood Pellets
HHV Substrate	[MJ/kg]	11,4	17,6	19,2	20,2	19,2	19,7
Syngas	[m.-% DM]	26,5	31,7	43,4	40,9	41,2	39,1
Liquid	[m.-% DM]	12,9	24,3	26,2	33,9	33,9	37,0
Char	[m.-% DM]	60,6	44,0	30,4	25,2	24,9	23,9
Syngas	[MJ/kg]	11,5	11,3	11,9	13,3	13,2	15,3
Liquid	[MJ/kg]	13,8	10,9	16	13	11,6	12,8
Char	[MJ/kg]	8,0	16,9	25,7	32,2	31,6	33,9
Carbon	[m.-%]	18,1	51,5	69,0	87,1	85,7	88,9
Stable part	[m.-%C]	97,7	98,4	100	87,2	92	86,8
Density	[kg/m³]	439	126	245	126	278	309

Quelle: NSR INTERREG Ivb, Brownsort 2013, unpublished

Utilization paths

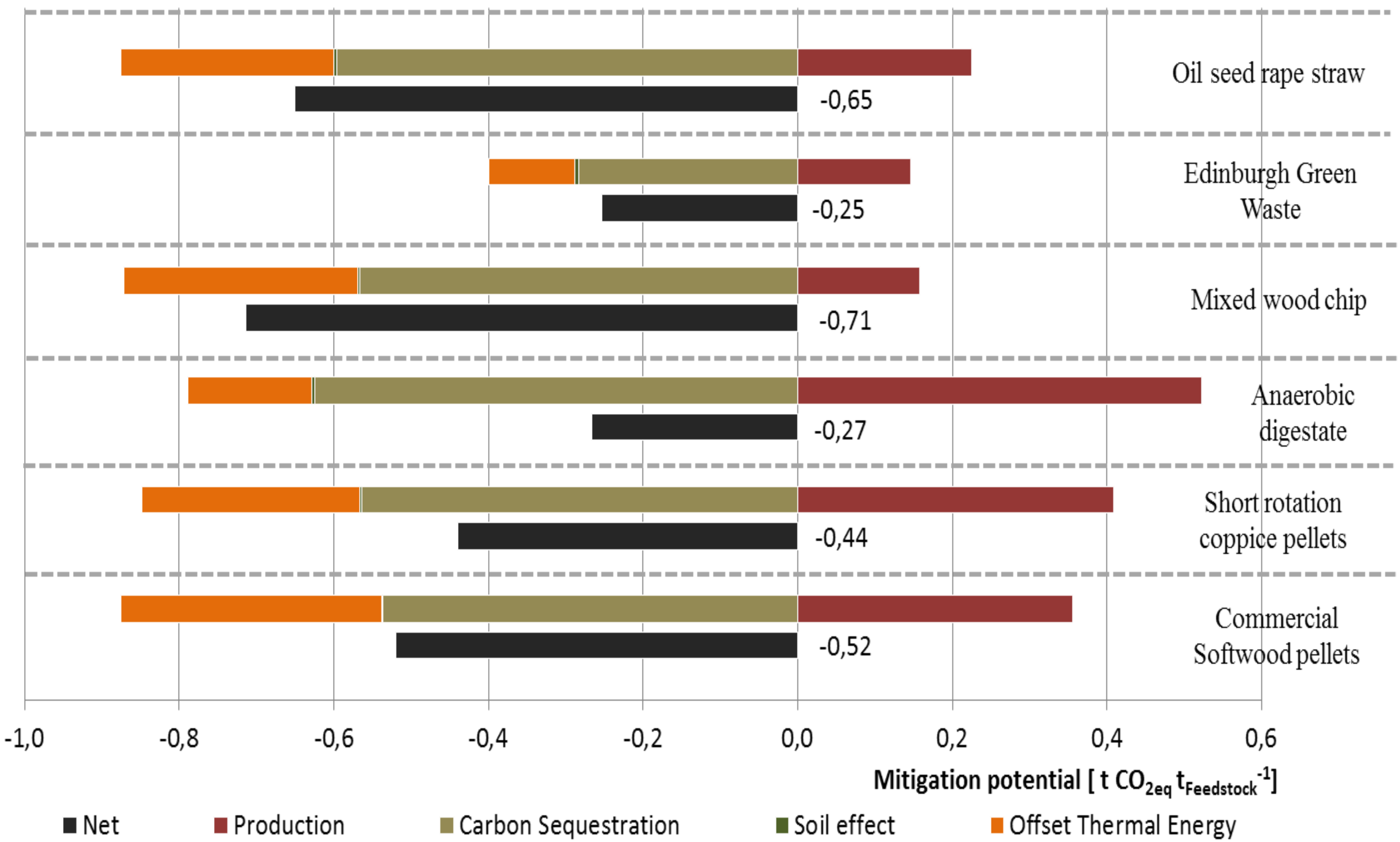
Considered facts in the conservative assessment:

- Carbon content and stability factor
- Labile Carbon
- Higher heating value
- SOC-Priming Effect
- Liming
- Nitrogen
- Phosphorous
- Heat and power offset for Europe
- Soil effects of 5 years (e.g. savings of mineral fertilizer)

Sensitivity analysis:

- Change in soil emissions (CO_2, N_2O and CH_4)
- Change in crop production
- Change in fertilizer intensity
- Increase of soil organic carbon
- Specific emission factors for heat and power plants in 6 different countries and direct substitution of fossil fuel

Greenhouse Gas Mitigation Potential for Application in Soil



Rödger et al (2013), currently under review

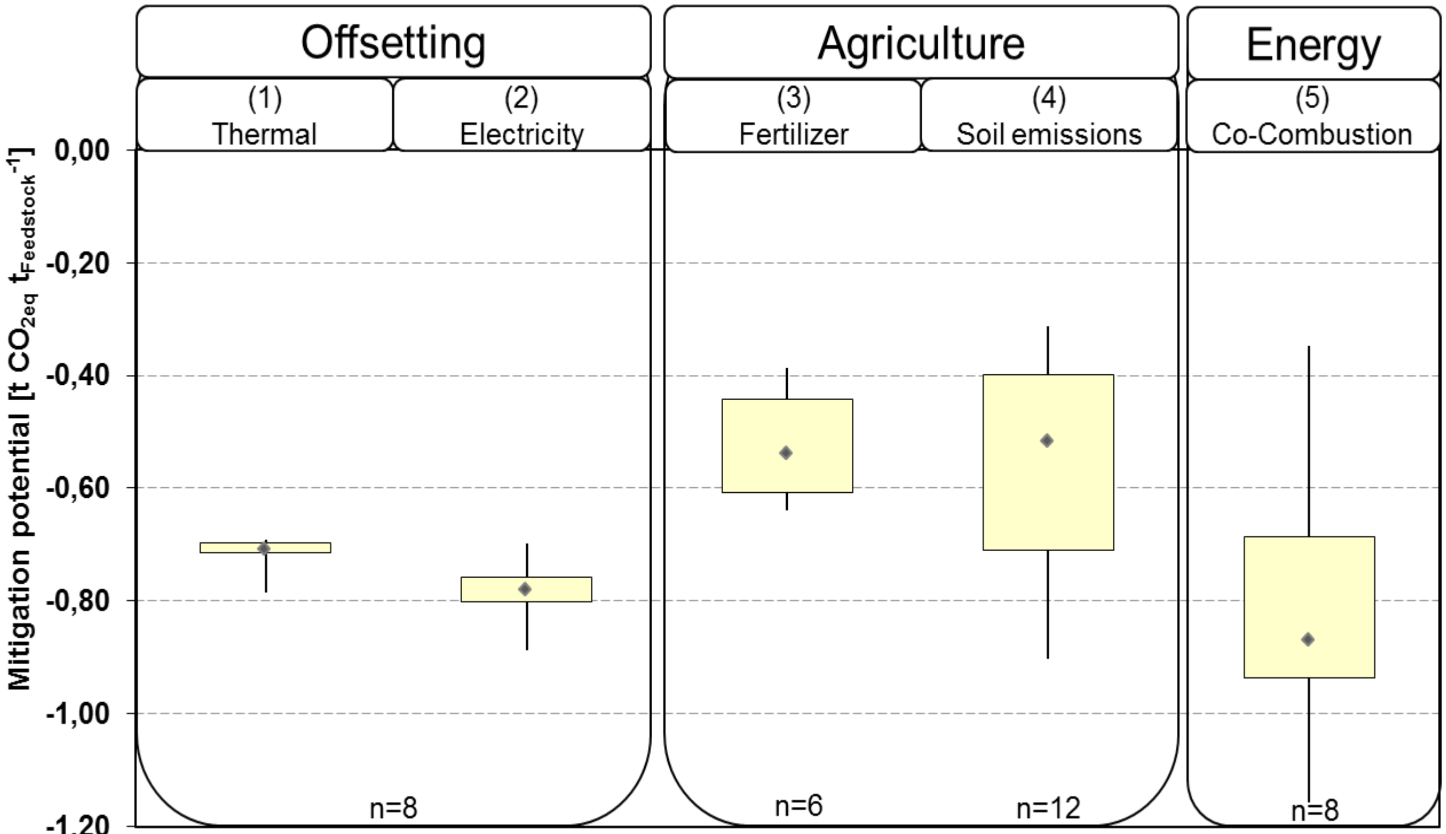
Mitigation values based on materials along the process chain

Global Warming Potential		Commercial Softwood Pellets	Short Rotation Coppice Pellets	Anaerobic Digestate	Mixed Wood Chip	Green Waste	Oil Seed Rape Straw Pellets
Substrate	[t CO_{2eq} $t_{Substrate}^{-1}$]	-0.21	-0.18	-0.08	-0.30	-0.11	-0.59
Feedstock	[t CO_{2eq} $t_{Feedstock}^{-1}$]	-0.52	-0.44	-0.27	-0.71	-0.25	-0.65
Char	[t CO_{2eq} t_{Char}^{-1}]	-2.57	-2.11	-0.73	-3.35	-0.49	-2.59

Rödger et al (2013), currently under review

- Mixed wood chips show best results
- Green waste and digestate have a high water content and need more energy for drying
- All biochars have the potential to mitigate GHG emissions

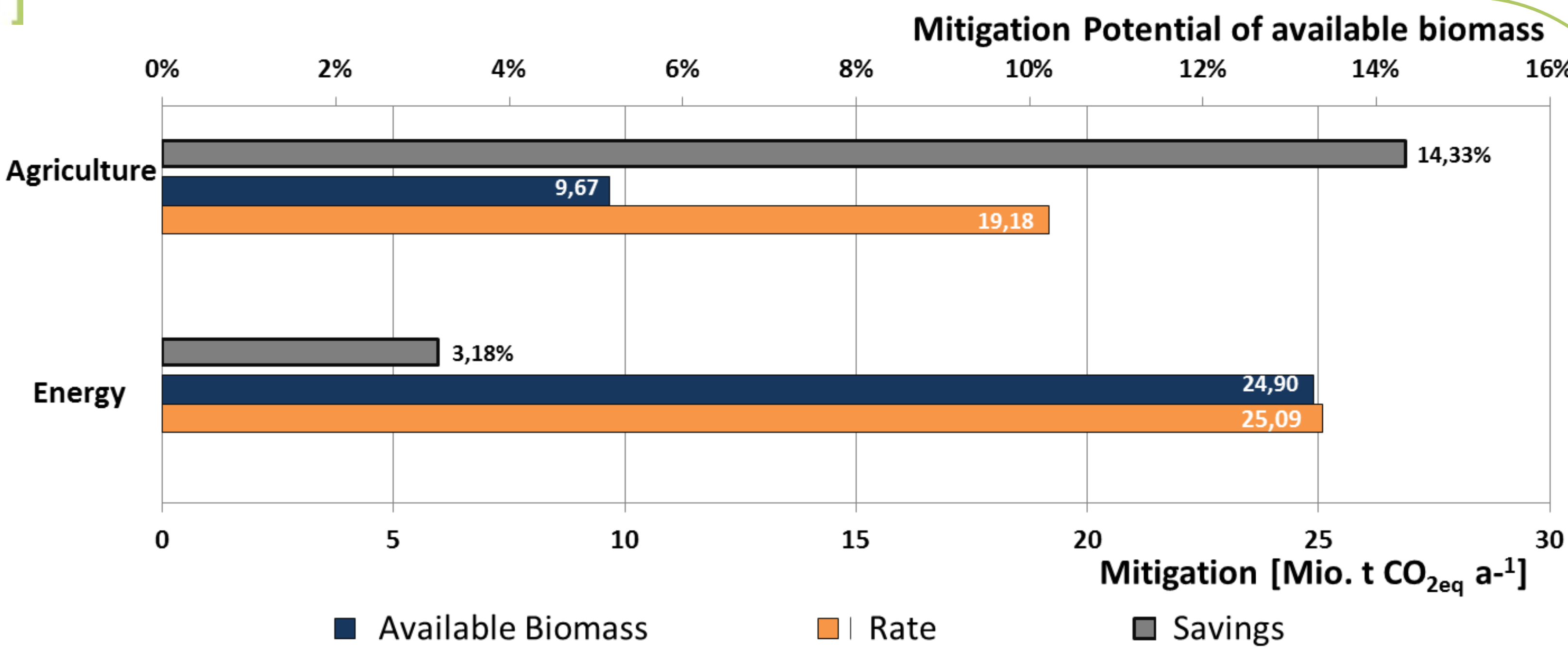
Sensitivity Analysis



Rödger et al (2013), currently under review

Input: - Mixed wood chips in (1), (2)and (5)
- Digfferent substrates in (3) and (4)

Spot on -> Germany



- **Agriculture:**
- 10 t Biochar per hectar (conservativ approach)
- 5 % of arable land is used per year (0,845 Mio. ha)
- Savings of about 9,7 Mio. t CO2eq a^{-1} (14,33 % of total emissions from the agriculture)
- **Energy Sector:**
- Substitution of 10 % (4,3 Mio. t) of the hard coal
- Savings of 24,9 Mio t CO2eq a^{-1} (3,18 % in the energy sector) are possible

Conclusion

- All biochars have the potential to mitigate GHG emissions

- Results strongly depend on local conditions (transport distances, soils type, grid mix etc.)

- Application in agruculture might have additional positive effects besides CO_2-mitigation

- If biochar is used for energy generation, energy carriers with highest emission (coal) should be replaced

- Additional benefits can derive if biochar is used in cascades (e.g. as feed additive first, than in a digester, and finally applied to soil)

THANK YOU VERY MUCH FOR YOUR ATTENTION!