Different energy conversion paths for reed - ecological and economic evaluation

ENEREED
Sustainable Energy Conversion from Reed Biomass

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BRINGT BESONDERES ZUSAMMEN

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Introduction

ENEREED (Sustainable Energy Conversion from Reed Biomass)

- Research project to investigate harvesting, processing technologies and thermal utilization possibilities for reed
- Technology investigation was done for harvesting and fuel processing (1st step)

  ⇨ results are basis for ecologic and economic evaluation

- Technology investigation was done for combustion (2nd step)

  ⇨ results are basis for ecologic and economic evaluation

- **Ecologic** and **economic** evaluation (3rd step)

Objective

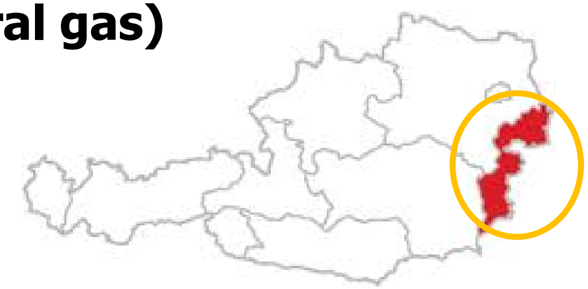
- Reed from the Lake Neusiedl in Austria is investigated as energy source for thermal utilization

- Evaluation of different harvesting technologies, treatments, supply chains and conversation possibilities

⇨ **Which is the best economic application scenario?**

⇨ **Which is the best ecologic application scenario?**

⇨ **Compare this to wood and fossil reference (fuel oil and natural gas)**



System description - application scenarios

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- Two types of harvesting equipment:
  - ordinary harvester with mow and hand-loading
  - harvester with mow and baler
- Two types of chopping technologies (2 machines)
- Several transport and storage possibilities
- Influence where transportation is placed in the production chain

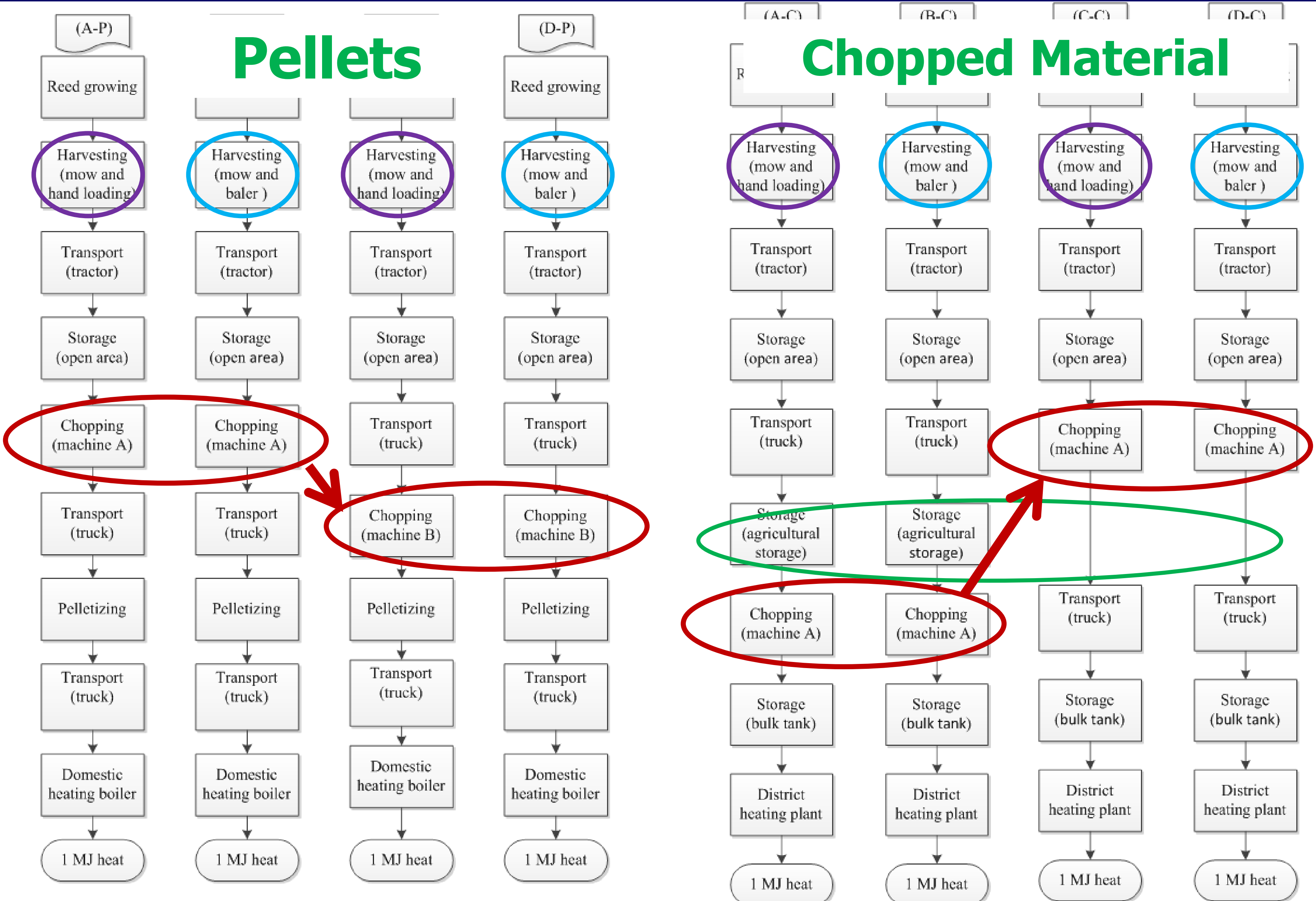
System description - application scenarios

- Different application scenarios using reed chopped short and reed as pellets are investigated
- Different supply chains are examined

↳ 2 particular cases using 100% reed:

  - Chips: 4 chains use reed in district heating plants
  - Pellets: 4 chains use reed in domestic heating boilers

Supply chains – reed pellets, chopped reed



Method
Economic evaluation

- Economic evaluation
  - for the fuel supply
  - for all investigated supply chains
- To get a good comparability all costs are indicated for 1t of reed (dry after harvesting)
- Data used:
  - from producers
  - field tests
  - literature or
  - own estimations
- 2 Methods:
  - direct costing approach
  - marginal abatement costs

Direct costing approach

To evaluate the supply chains:

- The process steps are calculated separately as cost objects
- Costing is done for fixed and variable costs
- Fixed costs include: capital costs (depreciation), interest on the tied capital, insurance and maintenance costs
- Variable costs consist of: salary, fuel and operating materials

Direct costing approach

Calculation scheme for fuel production costs:

Costs for equipment (investment)	Depreciation (residual value=0)
	Insurance
	Interest
Costs for equipment (operating)	Operating materials
	Repair and wear
	Rent
Labour costs	Salary seasonal workers
Costs for building and infrastructure	Depreciation
	Structural maintenance
	Insurance
	Interest
Surface fee	Lease
	Tax on land

Direct costing approach

Besides the scheme what was not taken into account:

- Land use - no costs are included in the calculation (no lease or tax on land)
- Chopping machine and tractor - charged only for the proportion of annual operating hours, which is necessary for the processing of reed

Results economic evaluation– reed pellets

4 different supply chains

A-P	[€ / t]	B-P	[€ / t]	C-P	[€ / t]	D-P	[€ / t]
Harvesting (mow, hand loading)	60.81	Harvesting (mow, bawler)	91.89	Harvesting (mow, hand loading)	60.81	Harvesting (mow, bawler)	91.89
Transport (tractor)	11.70	Transport (tractor)	11.85	Transport (tractor)	11.70	Transport (tractor)	11.85
Storage (open area)	0.35	Storage (open area)	0.35	Storage (open area)	0.35	Storage (open area)	0.35
Chopping (machine A)	11.57	Chopping (machine A)	11.57	Transport (truck)	24.17	Transport (truck)	27.62
Transport (truck)	11.60	Transport (truck)	11.60	Chopping (machine B)	19.01	Chopping (machine B)	19.01
Pelletizing	38.27	Pelletizing	38.27	Pelletizing	38.27	Pelletizing	38.27
Transport (truck)	4.64	Transport (truck)	4.64	Transport (truck)	4.64	Transport (truck)	4.64
Sum	**139**	**Sum**	**170**	**Sum**	**159**	**Sum**	**194**

- Basis - **1t$_{wb}$ Input**
- Differences are caused by the chosen harvesting and chopping technology
- Different result if transport before or after chopping (bulk density)

Results economic evaluation– chopped reed

4 different supply chains

A-C	[€ / t]	B-C	[€ / t]	C-C	[€ / t]	D-C	[€ / t]
Harvesting (mow, hand loading)	60.81	Harvesting (mow, bawler)	91.89	Harvesting (mow, hand loading)	60.81	Harvesting (mow, bawler)	91.89
Transport (tractor)	11.70	Transport (tractor)	11.85	Transport (tractor)	11.70	Transport (tractor)	11.85
Storage (open area)	0.35	Storage (open area)	0.35	Storage (open area)	0.35	Storage (open area)	0.35
Transport (truck)	24.17	Transport (truck)	27.62	Chopping (machine A)	11.57	Chopping (machine A)	11.57
Storage (agricultural storage)	6.83	Storage (agricultural storage)	9.18	Transport (truck)	11.60	Transport (truck)	11.60
Chopping (machine A)	11.57	Chopping (machine A)	11.57				
Sum	**115**	**Sum**	**152**	**Sum**	**96**	**Sum**	**127**

- Basis - **$1t_{wb}$ Input**
- Differences: varying structure of supply chains ⇨ A-C and B-C - extra storage hall
- Differences: harvesting technology and transport before or after chopping

Competitiveness of reed as fuel

- Results are compared to other fuels (wood chips and wood pellets) - typical used in the observed fields
- Calculation of an upper price limit for harvesting - depending on fuel market price
- In case of producing pellets: reed is already competitive to the market price - but a proper boiler technology has to be developed to handle the specific fuel properties
- The use of chopped reed is more interesting from an economic point of view - but the price is not competitive at the moment

Upper price limit for harvesting depending on fuel

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	Unit	Chopped reed	Reed Pellets
Upper price limit for fuel (adjusted to heating value)	[€/t_{wb}]	84 1)	190 2)
Transport (tractor)	[€/t_{wb}]	11.70	11.70
Storage (open area)	[€/t_{wb}]	0.35	0.35
Chopping	[€/t_{wb}]	11.57	11.57
Transport (truck)	[€/t_{wb}]	11.60	11.60
Pelletizing	[€/t_{wb}]	-	38.27
Transport (truck - pellets)	[€/t_{wb}]	-	4.64
Maximal costs for harvesting of reed	[€/t_{wb}]	49	112

1) Source: Prices for wood chips in Burgenland: (Landwirtschaftskammer. 2012)

2) Source: Average pellet prices 2003 to 2013 (Pro Pellets Austira. 2013)

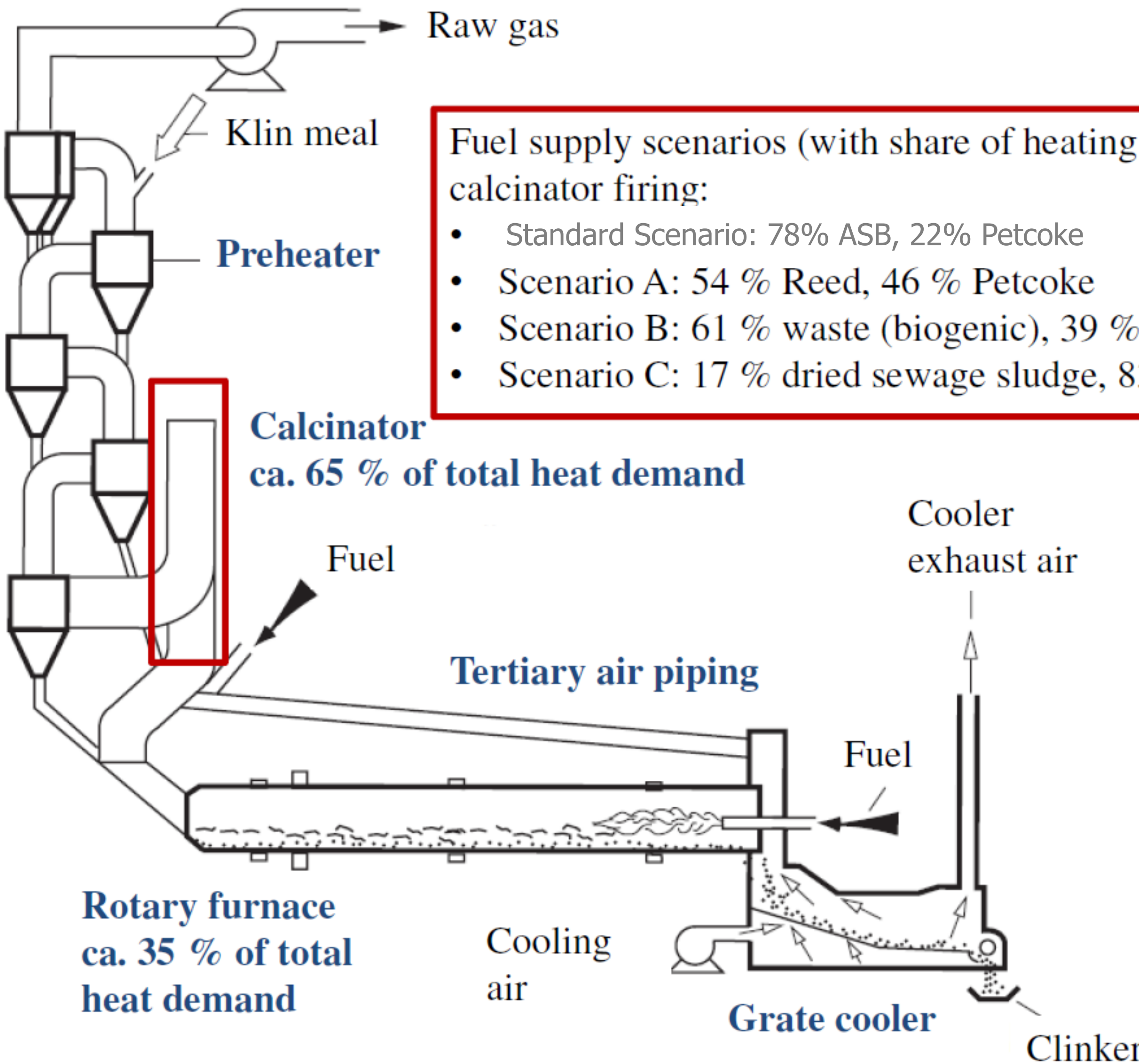
Marginal abatement costs cement industry

- <u>Comparison</u> of the costs for emission avoidance with the costs for purchasing emission allowances
- Marginal abatement costs for fossil-CO_2 allows an economic comparison of different <u>emission reduction possibilities</u>
- Difficult evaluation method because of interaction:
  - the costs of avoiding any extra ton of fossil CO_2 rise with every ton
  - actions affect not only on emissions - a reduction of energy demand, a change of fuel used may lead to changed fuel production costs
  - a change in fuel may cause adaptations of technology (change in fuel logistics)

Results economic evaluation – marginal abatement costs

Fuel supply scenarios (with share of heating demand) in calcinator firing:

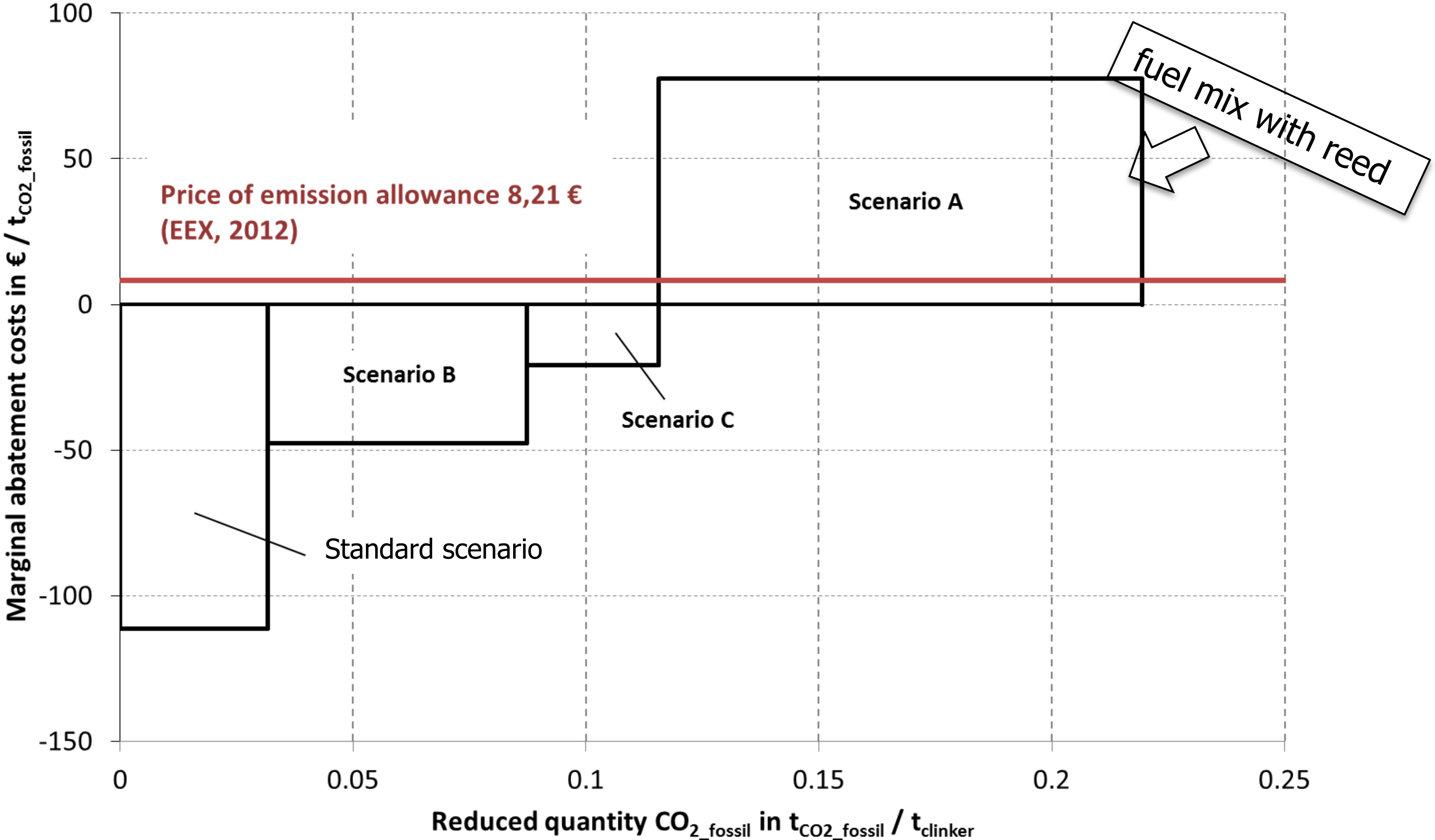
- Standard Scenario: 78% ASB, 22% Petcoke
- Scenario A: 54 % Reed, 46 % Petcoke
- Scenario B: 61 % waste (biogenic), 39 % Petcoke
- Scenario C: 17 % dried sewage sludge, 83 % Petcoke



Results economic evaluation – marginal abatement costs

- For calculation, data from own calculation of material production is used: the costs for the supply of chopped reed (supply chain C-C)
- Different scenarios of fuel mixes in the calcinatory are evaluated:
  - Standard scenario uses ASB (different residuals) and Petcoke
  - scenarios with different percentages of petrol coke and alternative fuels - reed (scenario A), sludge (scenario C) and waste (scenario B)
- Sensitivity analyses to reflect changes in market environment (energy costs, costs in emission trading market)
- Factors with significant influence: price of emission allowances and the price of the reference fuel (petrol coke)

Results economic evaluation– marginal abatement costs



The marginal abatement cost curve – energetic utilisation of reed compared with different fuel mixes and CO_2 emission allowances; reference uses 100% petcoke

Conclusion

- Using reed as a renewable fuel makes sense ⇨ regional resource
- Economic findings could enhance considerably, when inventing a more efficient harvesting technology
- Market competitiveness - reed pellets are competitive to wood pellets
- Market price for wood chips cannot be reached with chopped reed
- Marginal abatement costs of fossil CO_2 in cement industry showed that due to current market conditions, other alternative fuels are preferable to reed

Method

Environmental life-cycle assessment

Environmental life-cycle assessment:

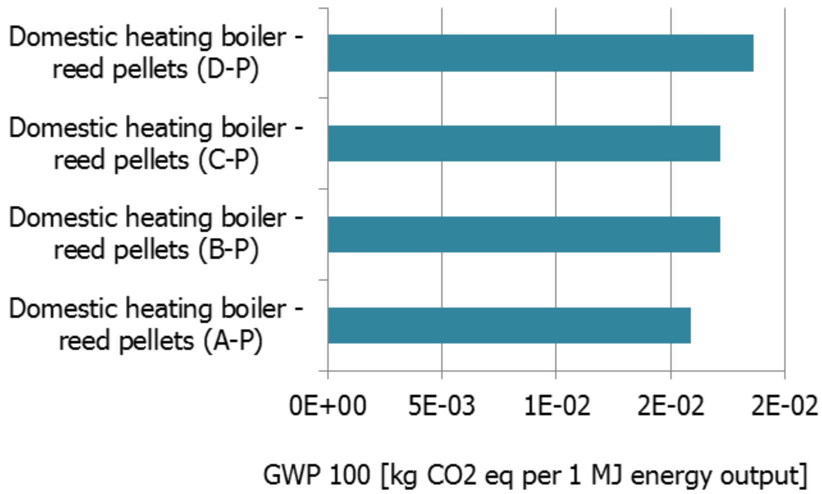
- Complies largely with the ISO 14000 series of LCA standards (EN ISO 14040, 2006 and EN ISO 14044, 2006)
- System function: energy supply of 1 MJ thermal energy from reed
- System boundaries:
  - Include upstream processes to manufacture technical devices, infrastructure for storage and transportation devices, transportation between the supply steps
  - CO_2 from biomass GWP = neutral
- Impact assessment, use of CML and ReCiPe methodology, following categories were examined:
  - Human toxicity (HTP), stratospheric ozone depletion (ODP), global warming potential (GWP 100), acidification potential (AP) and fine particulate matter emissions (PM)

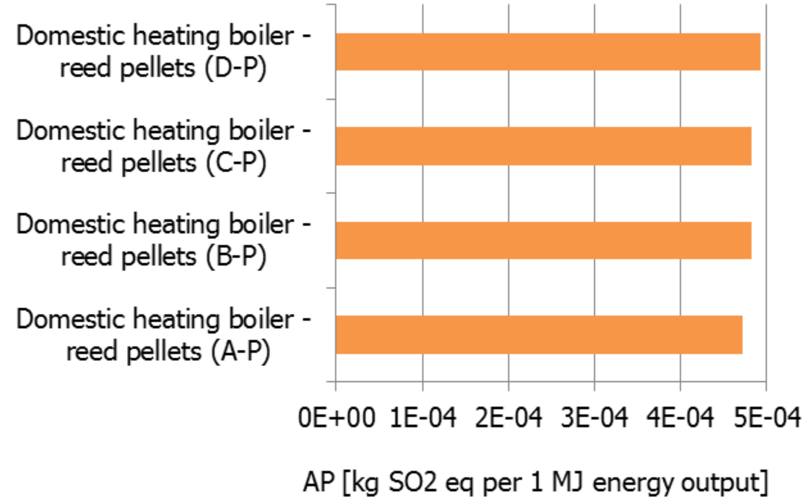
Results are presented

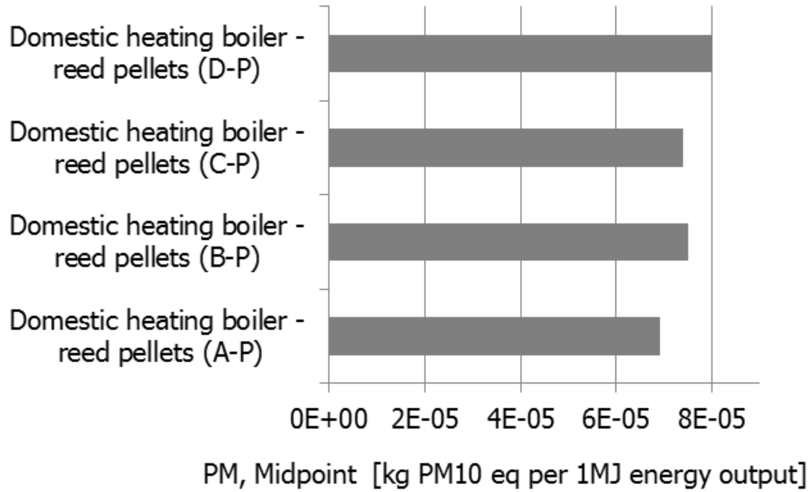
Method, cont'd
Environmental life-cycle assessment

- Data source:
  - Foreground data based on **field tests and own measurements** (harvesting, processing, transport and combustion)
  - Background data (infrastructure) & foreground data (transportation, fossil fuel systems, ash disposure) from the ecoinvent database version 2.1 (Swiss Centre for Life Cycle Inventories, St. Gallen, Switzerland)
- Data used:
  - Austrian or German origin
  - Background processes European and worldwide
  - Most data used are more recent than 2005

Results - application scenario pellets

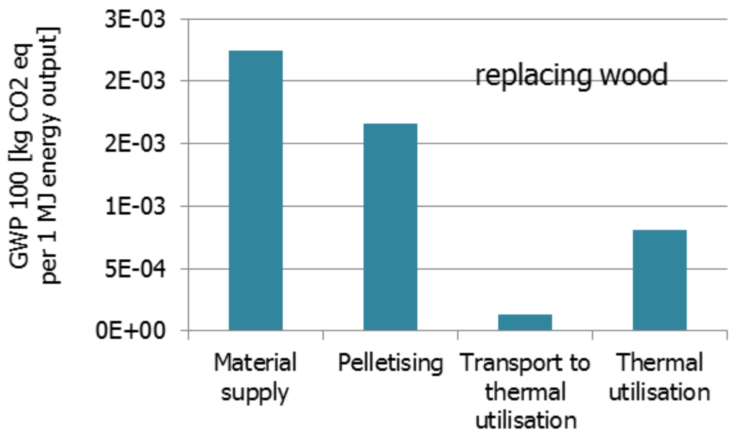


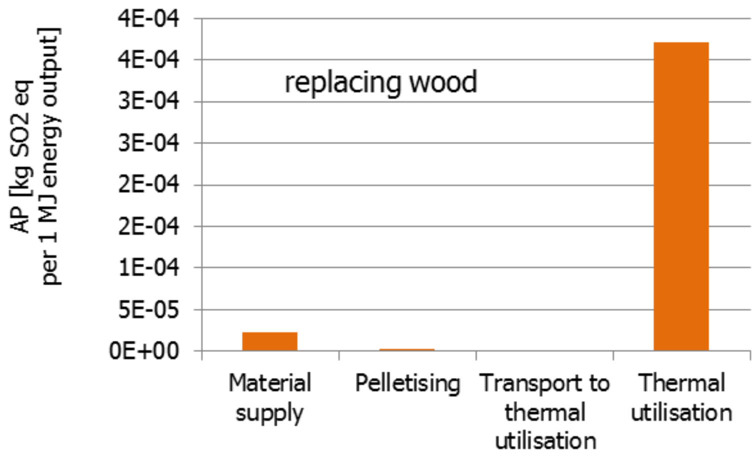


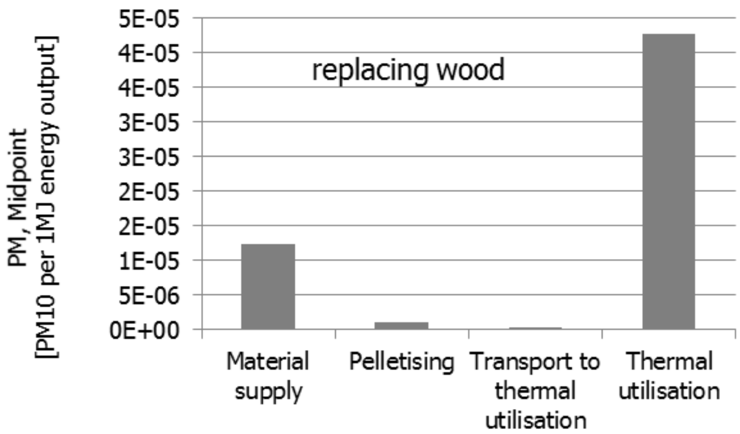


- Results are within less than +/- 10% of the arithmetic average in each category
- Differences are caused by the chosen harvesting and chopping technology
- Different result if transport takes place before or after chopping (bulk density)

Best scenarios reed pellets compared to wood pellets

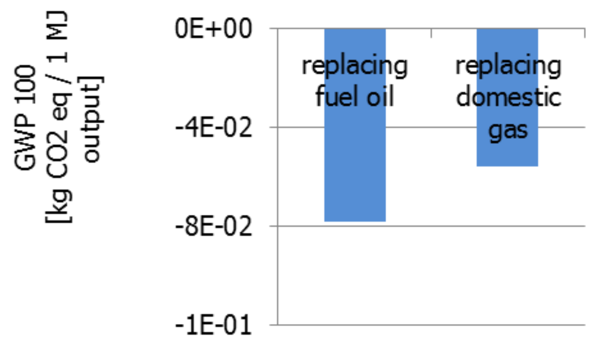


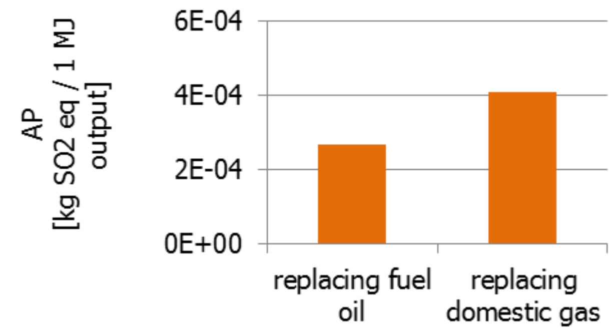


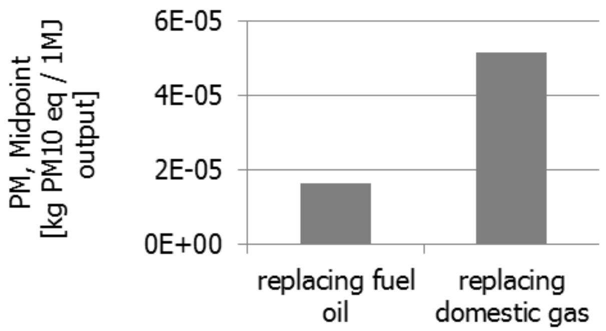


- Wood pellets harvesting of timber is not included ⇨ waste wood from timber industry (material supply)
- Wood has a higher energy density per mass (pelletizing, transport)
- Reed pellets have a higher sulphur content - AP and PM (thermal utilisation)

Best scenario reed pellets compared to fossil

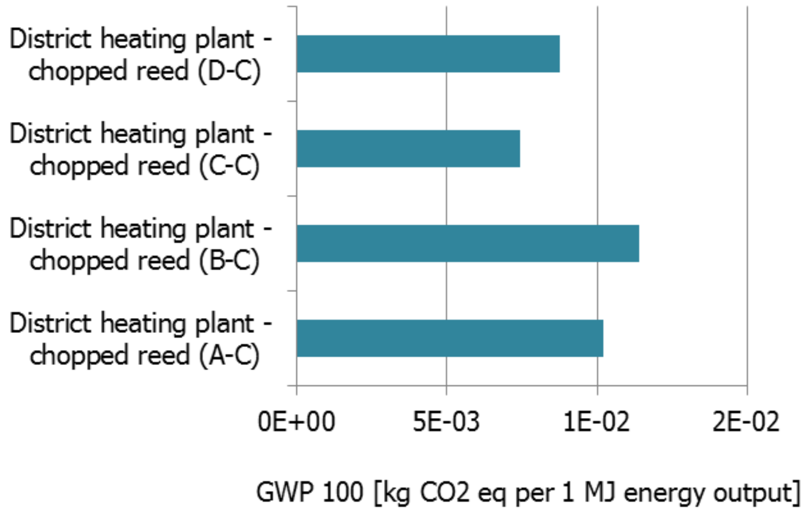


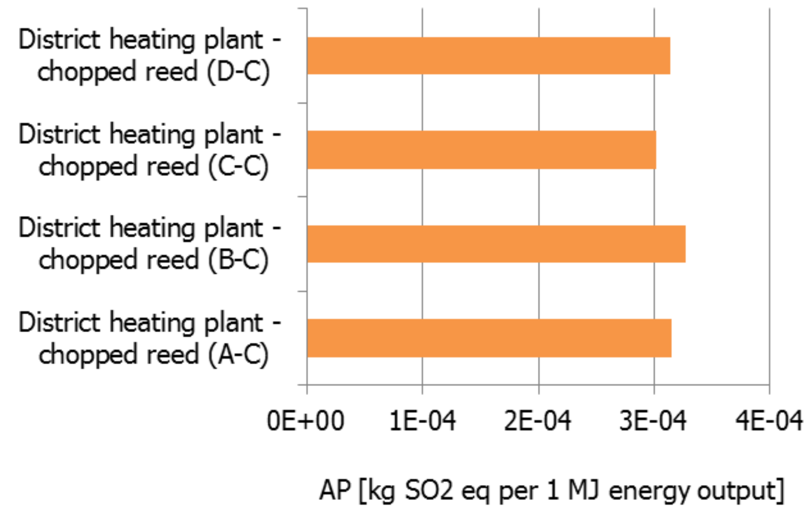


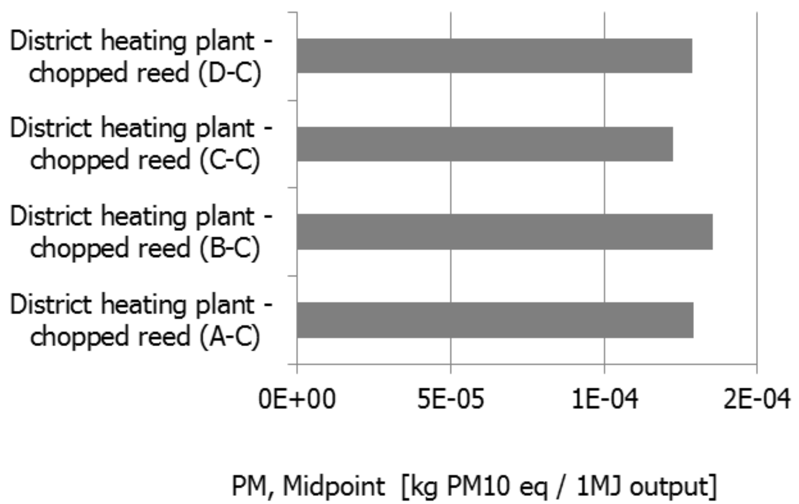


- Reed scenario: lowest overall specific GWP 100 – raise emissions by replacing
- Reed scenario: high ratio of sulphur (reed) results in high values for AP and PM – raise emissions by replacing

Results - application scenario chopped material

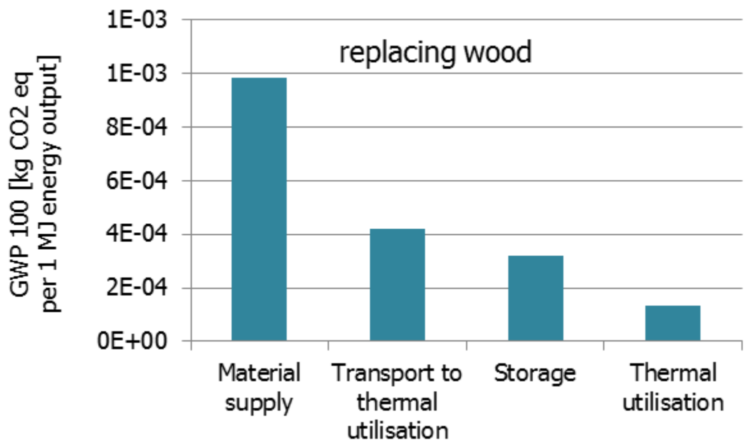


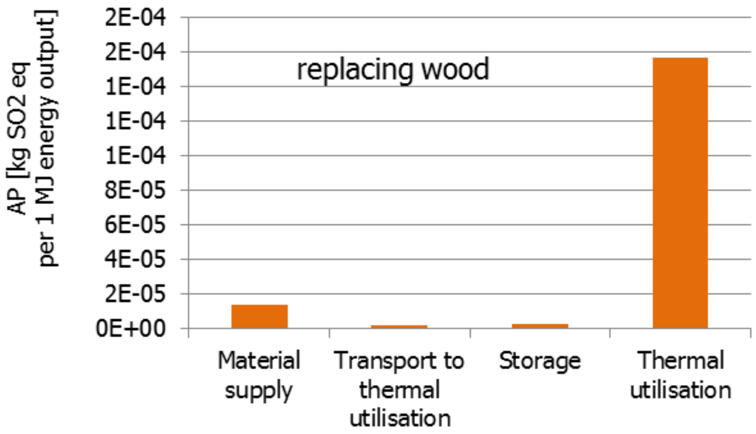


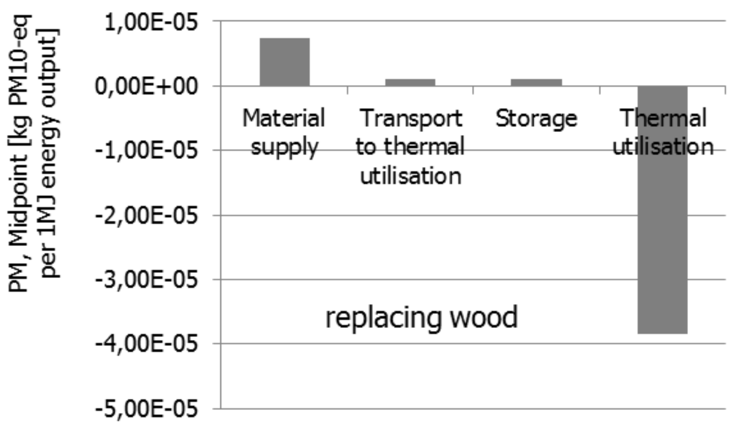


- Results are within about +/- 25% of the arithmetic average in each category
- Difference because of varying structure of the supply chains ⇨ A-C and B-C - extra storage hall
- Differences because of harvesting technology and if transport takes place before or after chopping

Best scenarios chopped reed compared to wood chips







- Lower energy amount for harvesting wood (reed - no state of the art techniques)
- Wood chips have a much higher bulk density than reed ⇨ important for transportation; not so storage (volume)
- Combustion:
  ⇨ higher sulphur emissions were measured for burning reed
  ⇨ lower PM measured for burning reed

Best scenario chopped reed compared to fossil

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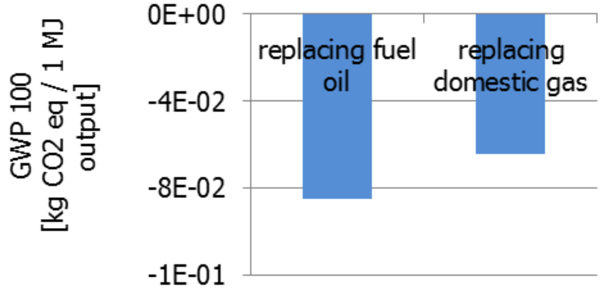

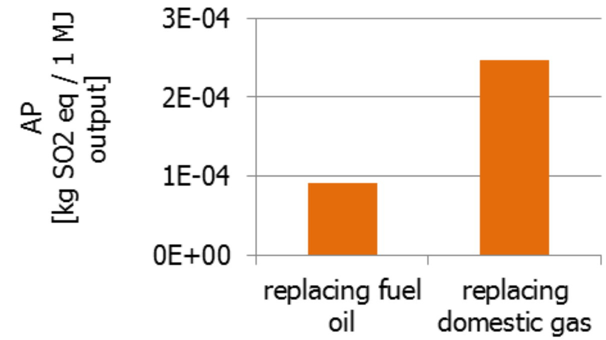

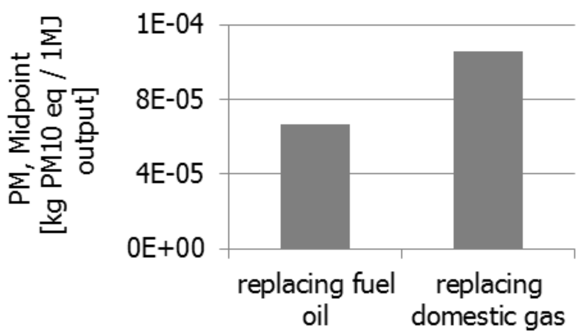

- Reed scenario: lowest overall specific GWP 100 – raise emissions by replacing
- Reed scenario: high ratio of sulphur (reed) results in high values for AP and PM – raise emissions by replacing
- PM emissions: ⇨ caused by particles, sulphur dioxide and nitrogen oxides

Conclusion

- Using reed as a renewable fuel makes sense ⇨ regional resource
- Environmental findings could enhance considerably, when inventing a more efficient harvesting technology
- Environmental analyses indicate that using reed as chopped material has the lowest overall specific GWP 100 compared to reed pellets and natural gas and light fuel oil
- Using reed shows a high ratio of sulfur which results in higher values for AP and PM (secondary PM10 emissions are formed)

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Harvesting Technology

Amt der Burgenländischen Landesregierung

Cultivation,
Fuel Supply

Esterházy

Land Owner,
Cultivation

WWF

Environmental Protection,
Sustainable Cultivation

Lafarge Zement

Industrial Conversion

Herz

Thermal Conversion
Small Scale Plant

Biomasse Fernheizwerk Güssing

Thermal Conversion
Large Scale Plant

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