Universiteit Utrecht

REFAWOOD

ERA-NET Bioenergy

Waste wood combustion: environmental consequences of using low-cost additives

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at the World Sustainable Energy Days 2019.
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INTRODUCTION

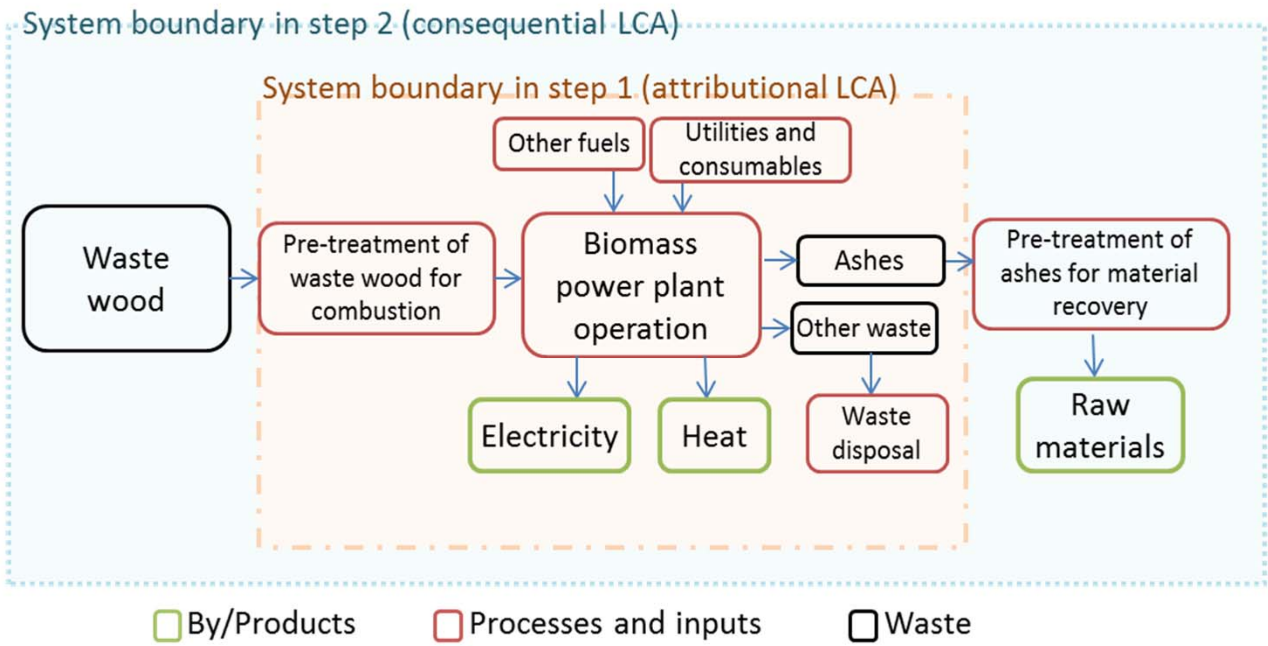
REFAWOOD **Resource-efficient fuel additives for reducing ash related operational problems in waste wood combustion**

- **WP: Evironmental and economic analysis**
- Life Cycle Assessment of electricity and energy produced from waste wood combustion with and without additives.

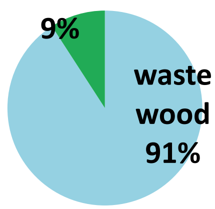
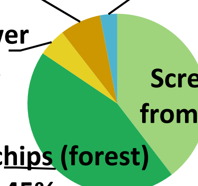
LIFE CYCLE ASSESSMENT: STEP 1

- **GOAL:** Environmental impacts of waste wood combustion using additives.
- LCA of **3 different power plants** (baseline + additives scenario).
- **FU:1 kWh & 1 MJ** (Exergy allocation). 1 year operation
- SimaPro software, ILCD 2011 Midpoint, CED
- Inventories:
  - Primary data from power plants (no infrastructure)
  - Secondary data from ecoinvent and EMEP/EEA air pollution inventory guidebook

CONSIDERED SYSTEM BOUNDARIES IN ENVIRONMENTAL ASSESSMENT



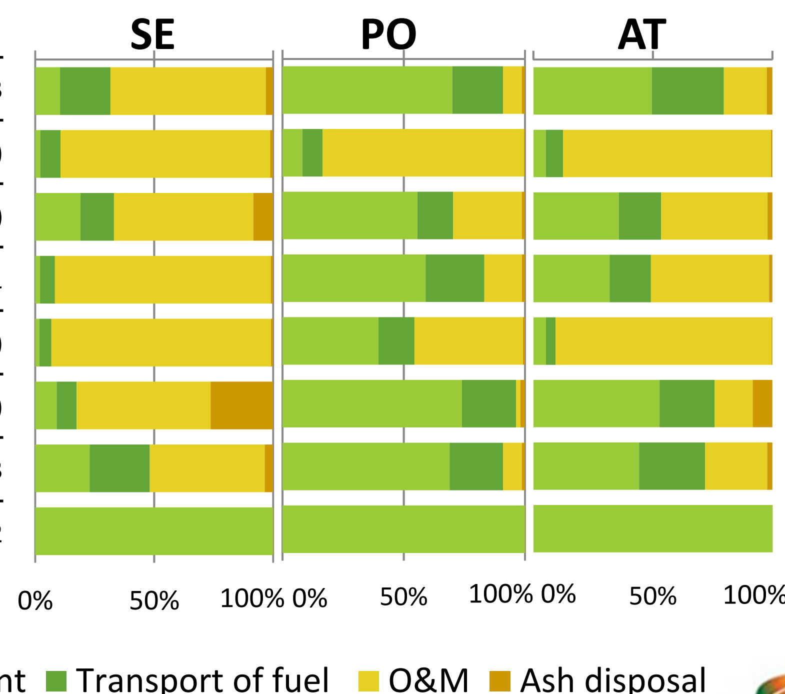
MAIN PARAMETERS IN EACH CASE STUDY

	SE	PO	AT
Location			
Installed capacity, MW	22 MW_e	1,2 MW_e	10 MW_e
Net electricity, MWh	47.000	7.973	73.309
Net heat, GJ	669.600	134.885	120.312
Net energy efficiency, %	74%	78%	33%
Average fuel transportation distance, km	164	50	55
Ash disposal	Landfill cover	Road stabilization	cement industry and landfill
Fuel blends, in %Primary energy			

CHARACTERIZED IMPACTS BASELINE SCENARIO

Contribution of the life stages to total impacts

Values	/kWh$_e$	/MJ$_{th}$
Climate change, *g CO_2 eq (fossil)*	38 – 52	2,3 – 9,3
Toxicity, non-cancer, *CTUh*	1,7-2,1 (x10^{-8})	1,2-1,6 (x10^{-9})
Toxicity, cancer, *CTUh*	4,0-5,7 (x10^{-10})	2,8-10 (x10^{-11})
Particulate matter, *g $PM_{2.5}$ eq*	0,03-0,09	0,002-0,21
Acidification, *molc H+ eq*	5,2-18 (x10^{-4})	3,3-58 (x10^{-5})
Freshwater eutroph., *kg P eq*	6,8-13 (x10^{-7})	4,5-52 (x10^{-8})
CED, Non-renewable, *MJ*	0,53-0,79	0,04-0,13
CED, Renewable, *MJ*	12-19	0,8-1,2



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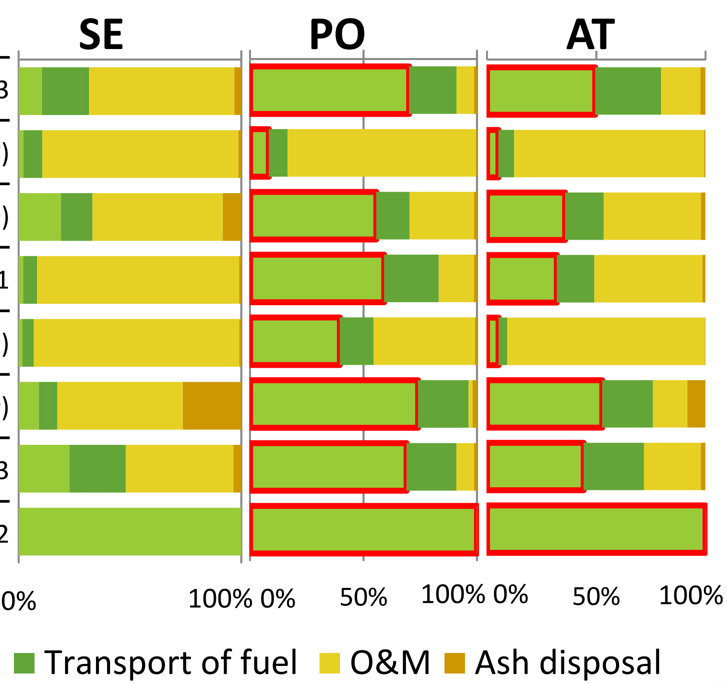

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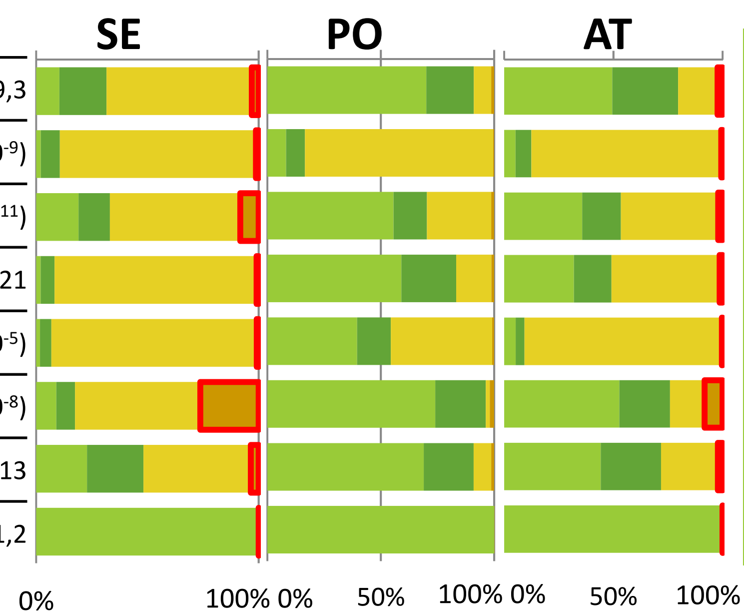


Fuel procurement | Transport of fuel | O&M | Ash disposal

OPERATION WITH LOW-COST ADDITIVES

- Expected changes estimated from short-period tests
- Change in (measurements and/or expert estimations):
  - Emissions
  - Ashes generated
  - Flue gas cleaning agents
  - Energy efficiency
  - Additives (waste)
- High uncertainty

OPERATION WITH LOW-COST ADDITIVES

Impact categories	U/kWh	Gypsum (0,5%)	Gypsum (1%)	Halloysite (1%)	Gypsum (1%)	Coal fly ash (3%)
Increase net energy efficiency		=	+1%	+3,7%	+1%	+0,5%
Increase cleaning agents		=	n/a	n/a	+20% lime	=
Change in emissions	HCl	=	+59%	-26%	+20%	=
	SO_2	=	+53%	-26%	+20%	=
	$PM_{2,5}$	=	-2%	+8%	-50%	=
	CO	=	-2%	-17%	=	=
	NOx	=	+14%	+14%	=	=

OPERATION WITH LOW-COST ADDITIVES

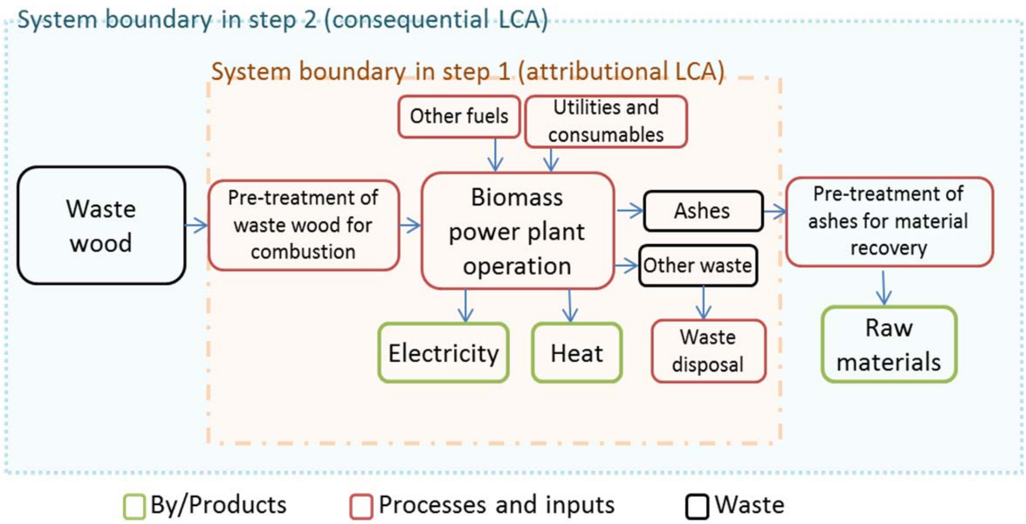
Per kWh electricity

Impact categories	U/FU	SE Gypsum (0,5%)	PO Gypsum (1%)	PO Halloysite (1%)	AT Gypsum (1%)	AT Coal fly ash (3%)
Climate change	g CO_2 eq	-0,1%	-0,4%	-3,6%	-2,0%	-1,5%
Human toxicity, non-cancer	CTUh	-0,03%	-0,8%	-4,6%	-3,2%	-1,8%
Human toxicity, cancer	CTUh	-0,2%	-0,4%	-3,6%	-3,0%	-1,6%
Particulate matter	kg $PM_{2.5}$ eq	-0,04%	-0,7%	-2,8%	-3,0%	-1,7%
Acidification	molc H+ eq	-0,1%	+6,4%	+0,7%	-3,2%	-1,8%
Freshwater eutrophication	kg P eq	-0,1%	-0,1%	-2,8%	-2,8%	-1,5%
CED, Non renewable	MJ	-1,2%	-0,4%	-3,5%	-2,8%	-1,5%
CED, Renewable	MJ	0,0%	-1,0%	-5,1%	-3,3%	-1,8%

STEP 2: CONSEQ. CHARACTERISED IMPACTS

BASELINE SCENARIO

Activities are modelled to the extent they are expected to change as a demand of the functional unit (1 kWh electricity, 1 MJ heat)



- displaced use of wood residues
- avoided landfill of additives
- avoided raw materials due ashes recycling
- displaced marginal technology for heat and electricity

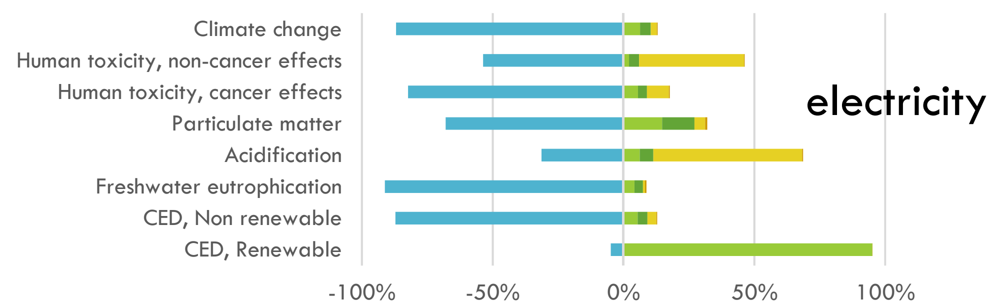
STEP 2: CONSEQ. CHARACTERISED IMPACTS

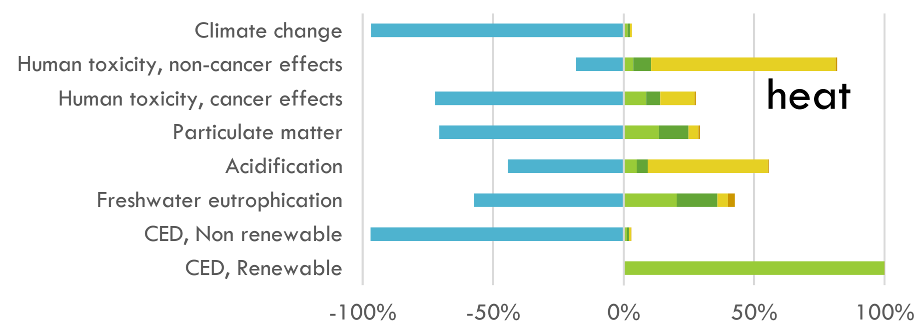
BASELINE SCENARIO

Example conseq results AT (baseline)

RESULTS

- Influence of avoided landfill of additives and ashes recycling is generally low (except for human non cancer toxicity)
- Main differences with respect to STEP 1 are related to the displacement of marginal technology





STEP2:OPERATION WITH LOW-COST ADDITIVES

Per kWh electricity

Impact categories	U/kWh	SE Gypsum (0,5%)	PO Gypsum (1%)	PO Halloysite (1%)	AT Gypsum (1%)	AT Coal fly ash (3%)
Climate change	g CO_2 eq	-0,0%	-0,1%	-1,1%	-0,3%	-0,3%
Human toxicity, non-cancer	CTUh	-0,0%	-0,8%	-5,7%	-20%	-11%
Human toxicity, cancer	CTUh	-0,0%	-0,3%	-2,1%	-0,8%	-0,4%
Particulate matter	kg $PM_{2.5}$ eq	-0,0%	-1,6%	-7,4%	-2,2%	-1,4%
Acidification	molc H+ eq	-0,0%	+247%	+0,6%	-0,3%	-3,3%
Freshwater eutrophication	kg P eq	-0,0%	-0,1%	-0,8%	-0,3%	-0,2%
CED, Non renewable	MJ	-0,0%	-0,1%	-0,9%	-0,4%	-0,3%
CED, Renewable	MJ	-0,0%	-0,8%	-5,6%	-3,9%	-2,2%

CONCLUSIONS

- Results are highly dependent on **fuel composition and combustion emissions**. Uncertainty
- Potential reduction impacts mainly due to energy efficiency increase. Additive impacts are minor (differences commercial sulphur negligible). Acidification increase.
- Using **gypsum**: **0-3%** reduction impacts, **halloysite**: **3-5%** reduction impacts, **coal fly ash**: **1-2%** reduction impacts depending on category and power plant (Median 1,8%).
- When considering a **consequential approach**, benefits with additives are relatively lower (compared to additives scenario) (**median 1% reduction** per kWh for different categories and additives). Exceptions on acidification.

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THANK YOU FOR YOUR ATTENTION

WASTE WOOD COMBUSTION: ENVIRONMENTAL CONSEQUENCES OF USING LOW-COST ADDITIVES

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