Fixed bed gasification and Cost Benefits analysis **including environmental analysis**

PHYTO2ENERGY

Phytoremediation driven energy crops production on heavy metal degraded areas as local energy carrier

IETU – Technical seminar

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ISPE

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Content

- Environmental analysis
- Logical scheme of the Cost benefits analysis
- Tutorial how to use the Excel file connected whit cost benefits analysis
- How to extract the conclusion of the cost benefits analysis

Cost benefits analysis for biomass gasification including environmental analysis

General Aspects:

- Multi - criteria analysis has taken into account environmental and social aspects for different energy recovery methods (small and mobile Gasification plants, large Gasification plants, incineration, pyrolysis), being analyzed and noted from the point of view of manufacturing, operation, end of use the four technologies
- Due to the oscillation into the energy market and on the UE ecological / energy policy, a calculation program as an excel file with a database that can be updated is proper for cost benefits analysis

The Excel database take into consideration the future available data, such as:

- Installation scale, investment cost, cost of the capital, price for the alternative fuel (natural gas, biomass, coal, petrol, etc), type of energy produced, price for the energy (thermal and electricity), labour cost, geographical position, maintenance cost, ecological aspects, EU legislation aspects, grant from UE and the government for RES.
- The excel file is designed as on open document that will be improved, adjusted and completed with the experimental results and updated data

Multi - criteria analysis
Environmental and social aspects

The environmental criterion	Small and mobile Gasification plants	Large Gasification plants	Incineration	Pyrolysis
Environmental resources for manufacturing	Small	Medium	Big	Big
Emissions during operation	Medium	Medium	Medium	Small
Residues for storage or other types of treatment - Ash and tar product	Medium	Medium	Medium	Small
Area occupied by the facility	Small	Big	Big	Medium
The lifetime of the installation	Medium	Big	Big	Medium
Number of Employees	Small	Medium	Big	Medium
Emissions from transport of biomass	Small	Big	Big	Big
Proven technology, performance	Yes, often used	Yes, often used	Yes, very often used	No, still at the pilot project stage
Acceptance by the population	Yes	No	No	Yes

Results for multi - criteria analysis

The environmental criterion	Small and mobile Gasification plants	Large Gasification plants	Incineration	Pyrolysis
Manufacturing	1	2	3	4
Operation	2	3	4	1
End of use	1	2	4	3
Total	**4**	**7**	**11**	**8**

The smallest note was given for the smallest impact on the environment, and the highest score for the highest environmental impact. The scores were summed up according to the criteria analyzed, and the best solution for energy recovery for HMC Biomass was **small and mobile Gasification plants**

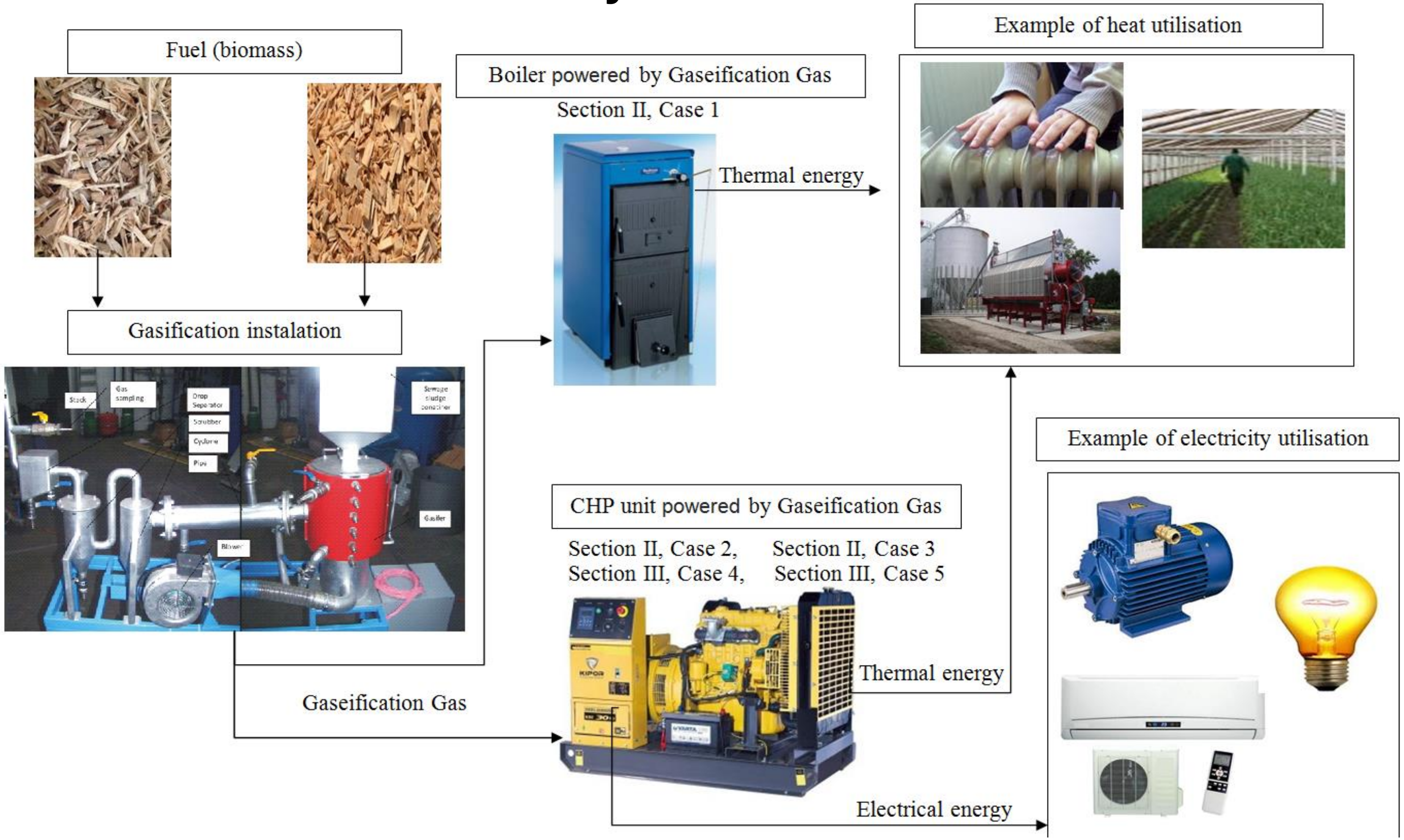
Cost benefits analysis for biomass gasification as local energy carrier

Logical schema of the Cost benefits analysis

Scenarios:

A. **CBA of HMC biomass gasification for heat generation vs. heat and electricity generation;**

B. **CBA of HMC biomass gasification vs. wood chips gasification for heat and electricity generation.**



Logical diagram for cost benefits analysis of HMC biomass gasification as local energy carrier

C1. (data from Pyto2Energy)
Biomass from the HMC area
- Biomass production
- Production cost of specific species / tone
- Physical and chemical properties of the biomass and of the obtaining product of the gasification (information about the biomass energy potential and chemical composition)

C3. (General assumptions for the cost benefits analysis)
- Remarks about the power capacity of the facility
- Data from partners database
- Data from literature review

C.2 (local energy requirements)
Consumers for produced energy (electrical and heating)
- Local community (heat and cooling)
- Smaller local factory (food processing, heating of greenhouse)
- Energy Supply for irrigation pumps
- Drying system (grain, fruits, vegetable drying)

C4.
Cost benefits analysis of HMC biomass gasification for heat vs. heat and electricity production
- investments cost
- operational cost
- energy balance
- ecological aspects
- UE legislation aspects

C5.
Cost benefits analysis of HMC biomass in comparison whit wood chips gasification for heat and electricity production
- investments cost
- operational cost
- energy balance
- ecological aspects

C.6
Results, conclusions and recommendations

Cost benefits analysis for biomass gasification as local energy carrier

Imput data about the required gaseification instalation and biomass fuel

Type of biomass	Gaseification gas burned in boiler: Estimate consum of biomass/thermal energy of produced gas burn in to the boiler [kg/kWh]	Gaseification gas used in CHP with Otto engine: Estimate consum of biomass / electric energy of produced gas in CHP Otto engine [kg/kWh]	Gaseification gas and Disel used in CHP with Disel engine (15% Diesel injection): Estimate consum kg/kWh biomass / electric energy of produced gas in CHP Diesel engine	Gaseification gas and Disel used in CHP with Disel engine (15% Diesel injection): Estimate consum [l/kWh] Diesel / electric energy of produced gas in CHP Diesel engine	Averege prod of biomass [tonnes/hectares*year]	Price €/ dry tone of biomass
Miscanthus giganteus	1.2	4.10	3.49	0.0630	25	60
Sida hermaphrodita	1.3	4.20	3.57	0.0630	22.5	60
Spartina pectinata	1.3	4.30	3.66	0.0630	19.5	60
Panicum virgatum	1.3	4.20	3.57	0.0630	19.5	60
Wood chips	1.1	4.00	3.40	0.0630	15	117

Parameters/ Country	Labour cost [Euro/hour]	Mantainance cost [%*Equipm cost/year]	Tax rate [%]	Electrical energy price [Euro/kWh]	Thermal energy price [Euro/kWh]	Income state subvention for RES [Euro/kWh]	Diesel price [€/ l]	Wood chips [Euro/tonnes]
Romania	1.97	0.02	19	0.12	0.0523	0.167	0.99	65
Poland	3.05	0.02	23	0.13	0.0386	0.153	0.956	102.5
Germany	8.84	0.02	31	0.29	0.073	0.185	1.129	131
Other Country	_	_	_	_	_	_	_	_

Parameters/ Country	Wood chips [Euro/tonnes]
Wood chips Romania	65
Wood chips Poland	102.5
Wood chips Germany	131
Wood chips Other Country	_

Price of gaseification instalation Euro/ KW		
Total power of the instalation Kw	gaseification instalation + boiler for thermal energy	gaseification instalation + CHP (electrical+ thermal energy)
inst<50kw	2800	4900

SECTION II

Cost benefits analysis of HMC biomass gasification for heat generation vs. heat and electricity production

Select the country of instalation	**Germany**
Select the Biomass intent to be use	**Miscanthus giganteus**

Case 1. Boiler powered by biomass gasification gas for thermal energy production

Instaled power of thermal energy only	61.0	Kw
Estimate consum of biomass forThermal energy only	73.2	kg/h
Working time	24.0	hour/day
	320.0	Day/year
	7680.0	hour/year
Total biomas /year	562.2	to/year
Estimate surface requaired per biomas selected	22.5	ha
Cost of the capital [%/year]	3.0	%/year
Total initial Investment cost that include the capital cost	247660.0	Euro
Life time of instalation	15	Years
Investment cost/year	16510.7	Euro/year
Fuel cost/ year	33730.6	Euro
Labour cost/ year	67891.2	Euro
Maintanance cost/ year	4953.2	Euro
Total cost	**123085.6**	Euro
Heat energy production	**468480.0**	kWh/year
income (Heat energy)	34199.0	Euro
Income state subvention for RES	0.0	Euro
Total Income	**34199.0**	Euro
Profit	-88886.6	Euro
Total Tax	0.0	Euro
Net Profit Euro/year	-88886.6	Euro/Year

Case 2. CHP with Otto engine powered by biomass gasification gas for electrical and thermal energy production

Instaled power of electrical energy CHP	35.0	Kw
Instaled power of thermal energy CHP	61	Kw
Estimate consum of biomass for electrical and thermal energy	143.6	kg/h
Working time	24	hour/day
	320	Day/year
	7680	hour/year
Total biomas /year	1102.52	to/year
Estimate surface requaired per biomas selected	44.10	ha
Cost of the capital [%/year]	3.0	%/year
Total initial Investment cost that include the capital cost	248774.5	Euro
Life time of instalation	15	Years
Investment cost/year	16585.0	Euro/year
Fuel cost/ year	66151.2	Euro
Labour cost/ year	67891.2	Euro
Maintanance cost/ year	4975.5	Euro
Total cost	**155602.9**	Euro
Heat energy production	**468480.0**	kWh/year
Electric energy production	**268907.5**	kWh/year
income (Heat Energy)	34199.0	Euro
income (electric Energy)	77983.2	Euro
Totel income (heat + electric Energy)	112182.2	Euro
Income state subvention for RES	49747.9	Euro
Total Income	**161930.1**	Euro
Profit	6327.2	Euro
Total Tax	1961.4	Euro
Net Profit Euro/year	4365.8	Euro/Year

Case 3. CHP with Diesel engine powered by biomass gasification gas and Diesel injection (15%) for electrical and thermal energy production

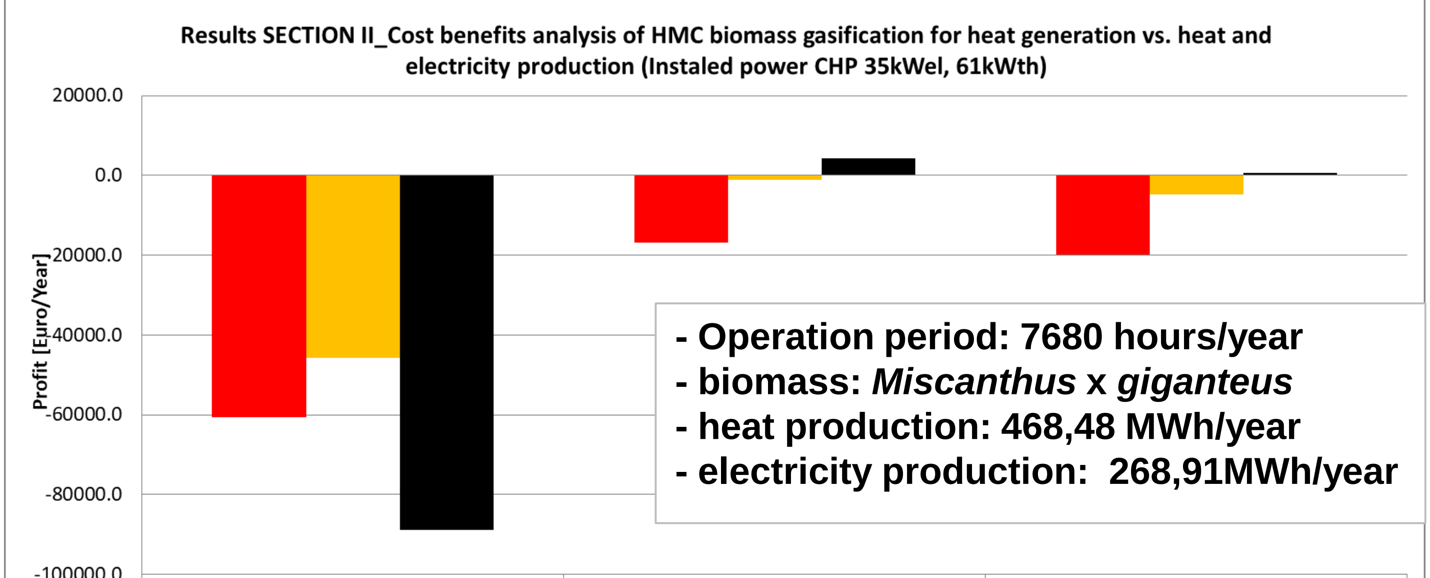
Instaled power of electrical energy CHP	35.0	Kw
Instaled power of thermal energy CHP	61	Kw
Estimate consum of biomass for electrical and thermal energy	122.0	kg/h
Estimate consum of Diesel for electrical and thermal energy	0.9	liters/h
Working time	24	hour/day
	320	Day/year
	7680	hour/year
Total biomas /year	937.14	to/year
Estimate surface requaired per biomas selected	37.49	ha
Cost of the capital [%/year]	3.0	%/year
Total Diesel /year	6968.31	liters/year
Total initial Investment cost that include the capital cost	248774.5	Euro
Life time of instalation	15	Years
Investment cost/year	16585.0	Euro/year
Biomass cost/ year	56228.6	Euro
Diesel cost/ year	7867.2	Euro
Total Fuel cost/ year	64095.8	Euro
Labour cost/ year	67891.2	Euro
Maintanance cost/ year	4975.5	Euro
Total cost	**153547.4**	Euro
Heat energy production	**468480.0**	kWh/year
Electric energy production	**268907.5**	kWh/year
income (Heat Energy)	34199.0	Euro
income (electric Energy)	77983.2	Euro
Totel income (heat + electric Energy)	112182.2	Euro
Income state subvention for RES	42285.7	Euro
Total Income	**154467.9**	Euro
Profit	920.5	Euro
Total Tax	285.4	Euro
Net Profit Euro/year	635.1	Euro/Year

Input data for cost benefits analysis in 2017

Type of cost / Country	Poland	Romania	Germany
Investment cost [Euro/kW] (thermal) installed (gaseification)	**2800**	**2800**	**2800**
Investment cost [Euro/kW] (electricity) (CHP unit) installed	**4900**	**4900**	**4900**
Labour cost [Euro/hour]	**3.05**	**1.97**	**8.84**
Maintenance cost [%*Total initial Investment cost/year]	**0.02**	**0.02**	**0.02**
Price for the *Miscanthus* x *giganteus* [Euro/tonne]	**105**	**115**	**105**
Price for the biomass (wood chips) [Euro/tonne]	**102.5**	**65**	**131**
Price for the Diesel in 2017 [Euro/liter]	**0.956**	**0.99**	**1.069**
Cost of the capital [%/year]	**3**	**3**	**3**
Grant from UE or government for RES [Euro/MWh]	**153**	**167**	**185**
Price for the thermal energy in 2017[Euro/kWh]	**0.0386**	**0.0523**	**0.073**
Price for the electrical energy [Euro/kWh]	**0.13**	**0.12**	**0.29**
Corporate tax rates [%]	**19**	**19**	**29.8**

Cost benefits analysis for biomass gasification as local energy carrier

A. CHP 35 kWel / 61 kWth

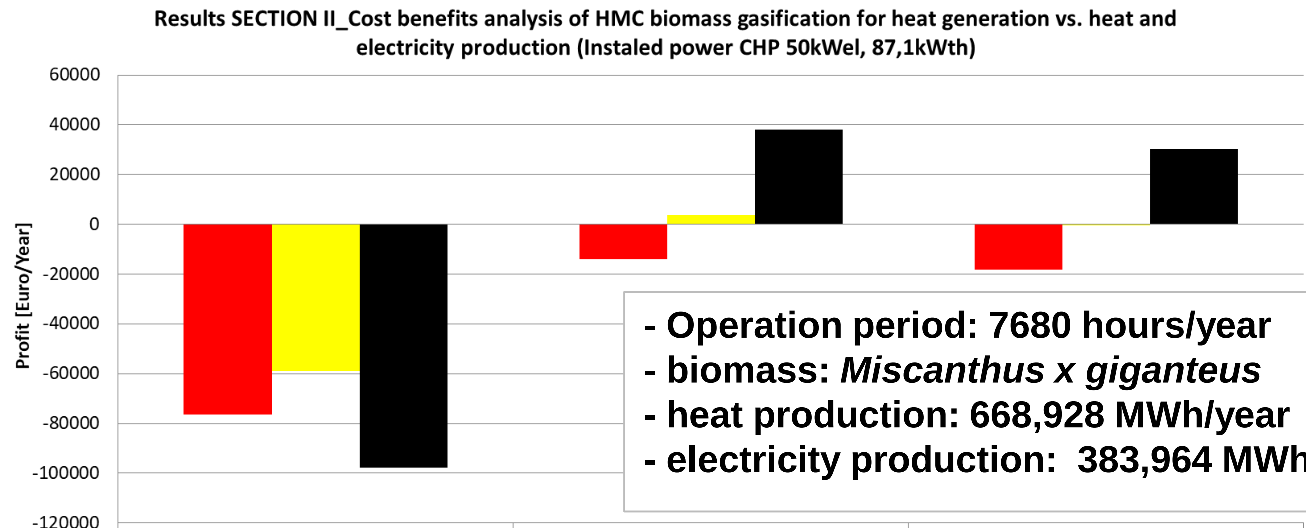


- **Operation period: 7680 hours/year**
- **biomass: *Miscanthus* x *giganteus***
- **heat production: 468,48 MWh/year**
- **electricity production: 268,91MWh/year**

	Case 1 Instaled power of thermal energy only (Net profit [Euro/year])	Case 2. CHP with Otto engine powered by biomass gasification gas for electrical and thermal energy production (Net profit [Euro/year])	Case 3. CHP with Diesel engine powered by biomass gasification gas and Diesel injection (15%) for electrical and thermal energy production (Net profit [Euro/year])
Poland	-60535.1	-16951.5	-19862.0
Romania	-45822.5	-1163.3	-4875.4
Germany	-88886.6	4365.8	635.1

Cost benefits analysis for biomass gasification as local energy carrier

A. CHP 50 kWel / 87.1 kWth

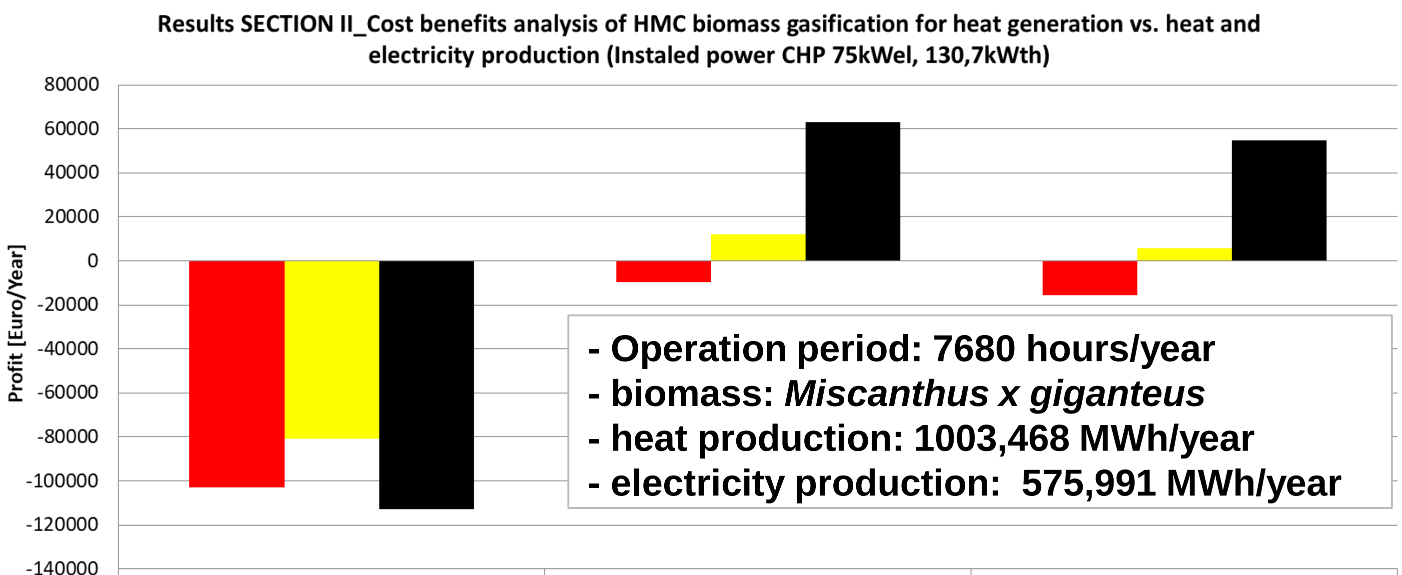


	Case 1 Instaled power of thermal energy only (Net profit [Euro/year])	Case 2. CHP with Otto engine powered by biomass gasification gas for electrical and thermal energy production (Net profit [Euro/year])	Case 3. CHP with Diesel engine powered by biomass gasification gas and Diesel injection (15%) for electrical and thermal energy production (Net profit [Euro/year])
Poland	-76414	-14182	-18338
Romania	-58955	3898	-488
Germany	-97870	38083	30363

- **Operation period: 7680 hours/year**
- **biomass: *Miscanthus x giganteus***
- **heat production: 668,928 MWh/year**
- **electricity production: 383,964 MWh/year**

Cost benefits analysis for biomass gasification as local energy carrier

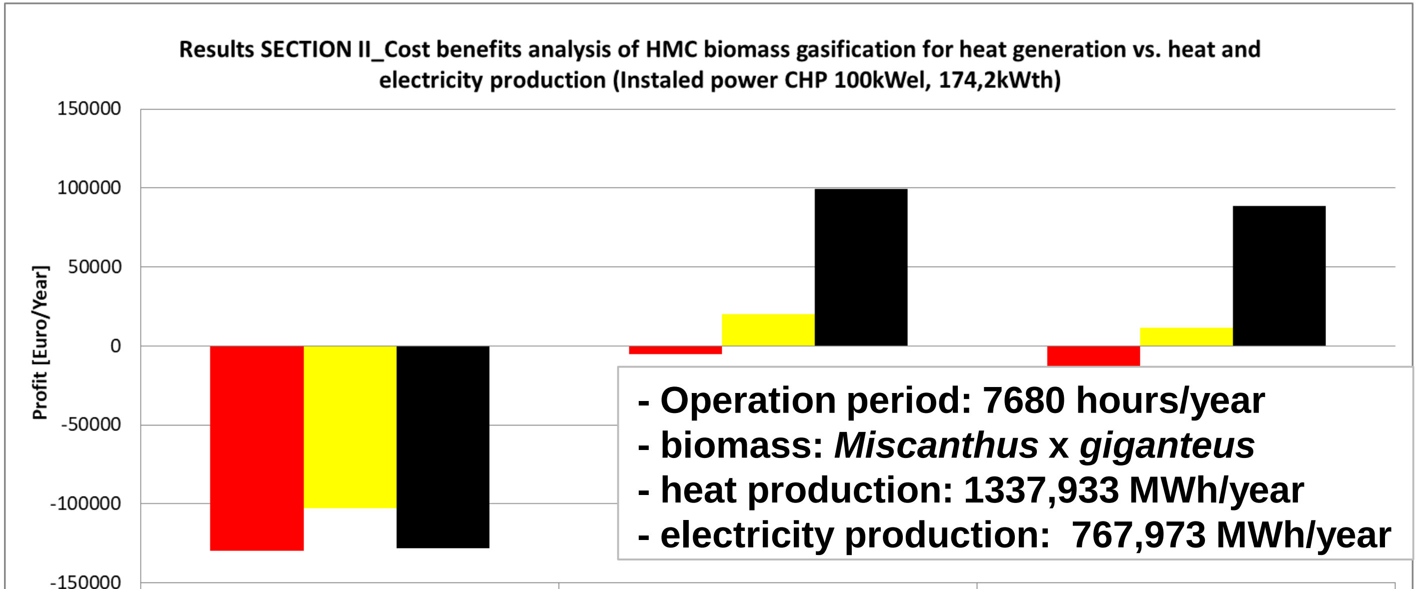
A. CHP 75 kWel / 130.7 kWth



	Case 1 Instaled power of thermal energy only (Net profit [Euro/year])	Case 2. CHP with Otto engine powered by biomass gasification gas for electrical and thermal energy production (Net profit [Euro/year])	Case 3. CHP with Diesel engine powered by biomass gasification gas and Diesel injection (15%) for electrical and thermal energy production (Net profit [Euro/year])
Poland	-102915	-9560	-15794
Romania	-80873	11976	5536
Germany	-112863	62847	54856

Cost benefits analysis for biomass gasification as local energy carrier

A. CHP 100 kWel / 174.2 kWth



- Operation period: 7680 hours/year
- biomass: ***Miscanthus* x *giganteus***
- heat production: 1337,933 MWh/year
- electricity production: 767,973 MWh/year

	Case 1 Instaled power of thermal energy only (Net profit [Euro/year])	Case 2. CHP with Otto engine powered by biomass gasification gas for electrical and thermal energy production (Net profit [Euro/year])	Case 3. CHP with Diesel engine powered by biomass gasification gas and Diesel injection (15%) for electrical and thermal energy production (Net profit [Euro/year])
Poland	-129404	-4940	-13251
Romania	-102781	20051	11466
Germany	-127849	99399	88753

Cost benefits analysis for biomass gasification as local energy carrier

B. CHP 35 kWel / 61 kWth

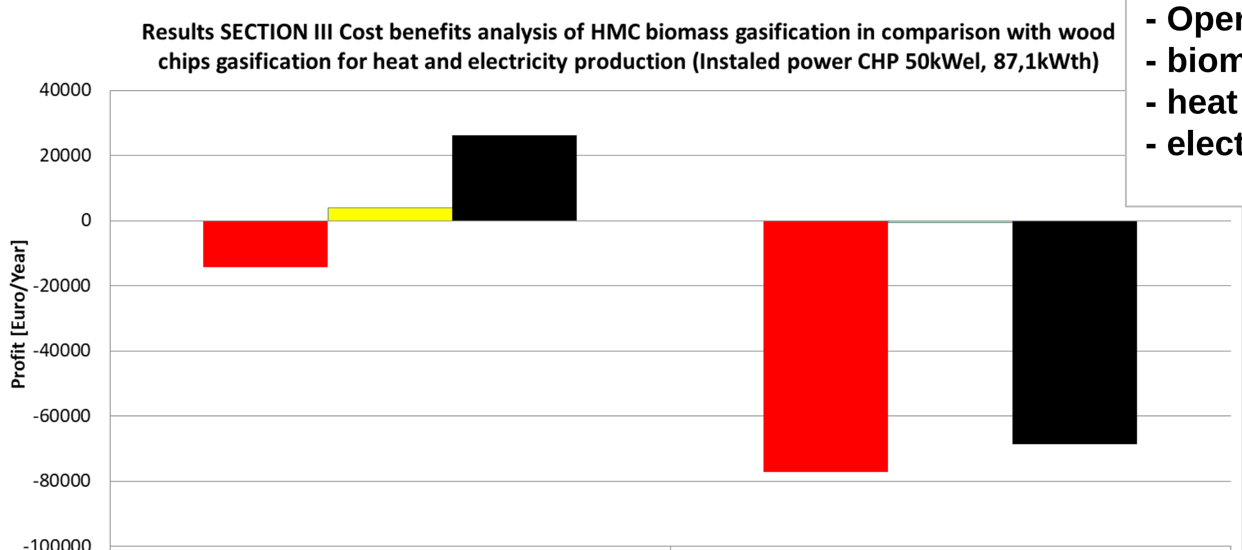
- **Operation period: 7680 hours/year**
- **biomass: *Miscanthus* x *giganteus***
- **heat production: 468,48 MWh/year**
- **electricity production: 268,91MWh/year**

Results SECTION III Cost benefits analysis of HMC biomass gasification in comparison with wood chips gasification for heat and electricity production (Instaled power CHP 35kWel, 61kWth)

	Case 4. CHP with Otto engine powered by biomass gasification gas for electrical and thermal energy production (Net profit [Euro/year])	Case 5. CHP with Otto engine powered by wood chips gasification gas for electrical and thermal energy production (Net profit [Euro/year])
Poland	-16951.5	-63808.7
Romania	-1163.3	-6675.9
Germany	4365.8	-71951.8

Cost benefits analysis for biomass gasification as local energy carrier

B. CHP 50 kWel / 87.1 kWth

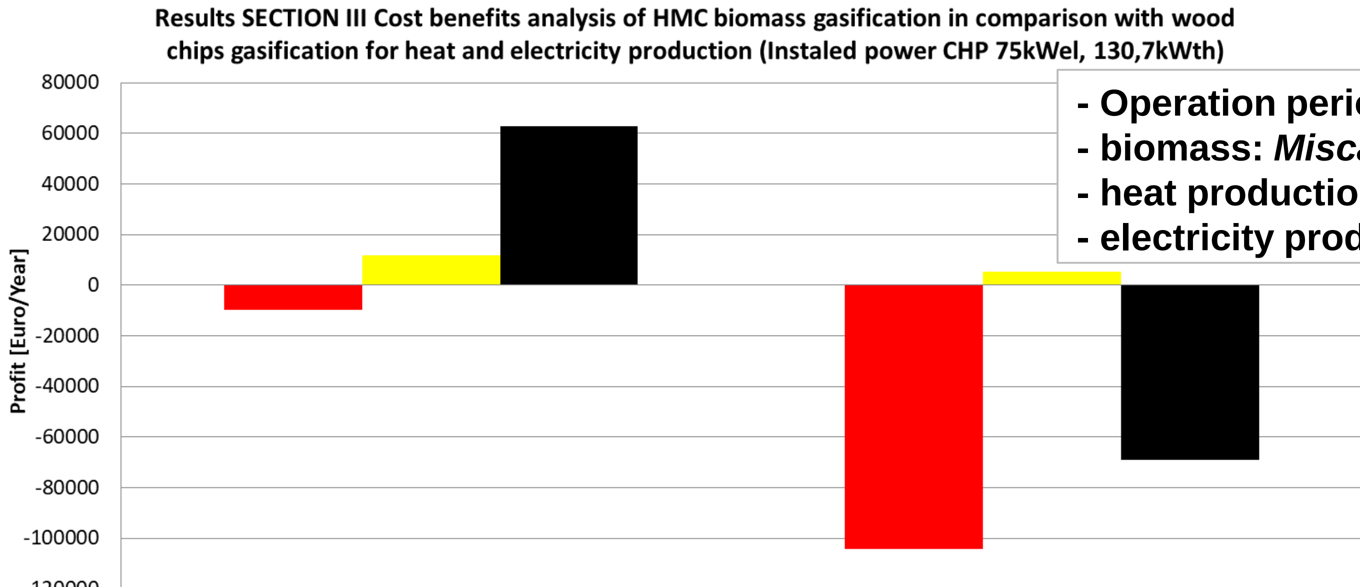


	Case 4. CHP with Otto engine powered by biomass gasification gas for electrical and thermal energy production (Net profit [Euro/year])	Case 5. CHP with Otto engine powered by wood chips gasification gas for electrical and thermal energy production (Net profit [Euro/year])
Poland	-14182	-77152
Romania	3898	-563
Germany	26277	-68659

- **Operation period: 7680 hours/year**
- **biomass: *Miscanthus* x *giganteus***
- **heat production: 668,928 MWh/year**
- **electricity production: 383,964 MWh/year**

Cost benefits analysis for biomass gasification as local energy carrier

B. CHP 75 kWel / 130.7 kWth



	Case 4. CHP with Otto engine powered by biomass gasification gas for electrical and thermal energy production (Net profit [Euro/year])	Case 5. CHP with Otto engine powered by wood chips gasification gas for electrical and thermal energy production (Net profit [Euro/year])
Poland	-9560	-104023
Romania	11976	5445
Germany	62847	-69043

- **Operation period: 7680 hours/year**
- **biomass: *Miscanthus* x *giganteus***
- **heat production: 1003,468 MWh/year**
- **electricity production: 575,991 MWh/year**

Cost benefits analysis for biomass gasification as local energy carrier

B. CHP 100 kWel / 174.2 kWth

Results SECTION III Cost benefits analysis of HMC biomass gasification in comparison with wood chips gasification for heat and electricity production (Instaled power CHP 100kWel, 174,2kWth)

	Case 4. CHP with Otto engine powered by biomass gasification gas for electrical and thermal energy production (Net profit [Euro/year])	Case 5. CHP with Otto engine powered by wood chips gasification gas for electrical and thermal energy production (Net profit [Euro/year])
Poland	-4940.374285	-130880.7867
Romania	20051.03994	11342.72117
Germany	99399.40325	-69427.25147

- **Operation period: 7680 hours/year**
- **biomass: *Miscanthus* x *giganteus***
- **heat production: 1337,933 MWh/year**
- **electricity production: 767,973 MWh/year**

Conclusions

- **A. Analyze of the obtained results of Cost benefits analysis of HMC biomass gasification for heat generation vs. heat and electricity generation offer the following conclusions:**

- If the gas obtained after gasification process of HMC biomass is used only for heat generation, in all the examined cases there is no profit. This is because the heating energy price is relatively small and the manufacturer does not get any subsidy from the state for renewable energy production in cogeneration.

- If the gas obtained after gasification process of HMC biomass is used to obtain the combined electricity and heat energy, the plant is generally profitable only if the installed electrical power greater then 50 kWel. For smaller installed capacity, the impact of labor cost are quite large and practically cancel any profits.

- As installed power of CHP plant is higher and also the number of operating hours is higher, the profit generated from the plant is higher.

Cost benefits analysis for biomass gasification including environmental analysis

Conclusions

- Best solution for energy recovery for HMC Biomass was **small and mobile Gasification plants**

- Comparing the amount of profit in the three countries (Poland, Romania, Germany) analyzed notice that practically amount of profit is higher in the countries where the price of electricity delivered is greater.

- Comparing the cogeneration plant that works in Case 2. CHP with Otto engine powered by biomass gasification gas for electrical and thermal energy production and Case 3. CHP with Diesel engine powered by biomass gasification gas and Diesel injection (15%) for electrical and thermal energy production we observe, that the plant with Otto engine has a higher profit for the same electrical power plant installed because in the Diesel Engine use 15% Diesel fuel and the subsidy is proportional energy generated by biomass fuel.

In all cases mentioned above, however, the decision to implement an installation may be taken even if the net profit obtained from the plant is negative, but the utilization of HMC Biomass in gasification installation generates benefits for environment and for society.

Conclusions

- **B. If we analyze the obtained results of “Cost benefits analysis of biomass gasification” in comparison with HMC wood chips for heat and electricity generation gasification; we can draw the following conclusions:**

- Due to the high value of the piece for wood chips in Germany and Poland, a CHP gasification plant that operates with such fuel is not feasible at the current price of fuel but the use of the HMC biomass in in generally feasible for plant whit the installed electrical power greater then 50 kWel.

- Rising prices in recent years of the wood chips in all the countries, make that a facility that operates with HMC biomass to be more profitable then the situation when the plant use wood chips as fuel.

Cost benefits analysis for biomass gasification including environmental analysis

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Thank you for your attention!

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