Co-firing biomass with fossil fuels – technological and economic evaluation based on Austrian experiences

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Overview

- Introduction
- Framework conditions for electricity production from biomass in Austria
- Technologies for co-firing biomass with fossil fuels
- Economic evaluation of the technologies investigated
- Sensitivity analyses regarding important parameters
- Summary

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Advantages of biomass co-firing

- Reduction of CO_2 emissions
- Potential for reduction of SO_x and NO_x emissions given (especially when wood fuels are utilised)
- Rapid creation of a large renewable energy market
- Efficient utilisation of biomass fuel resources
- Reduced capital costs in comparison to new biomass power or CHP plants

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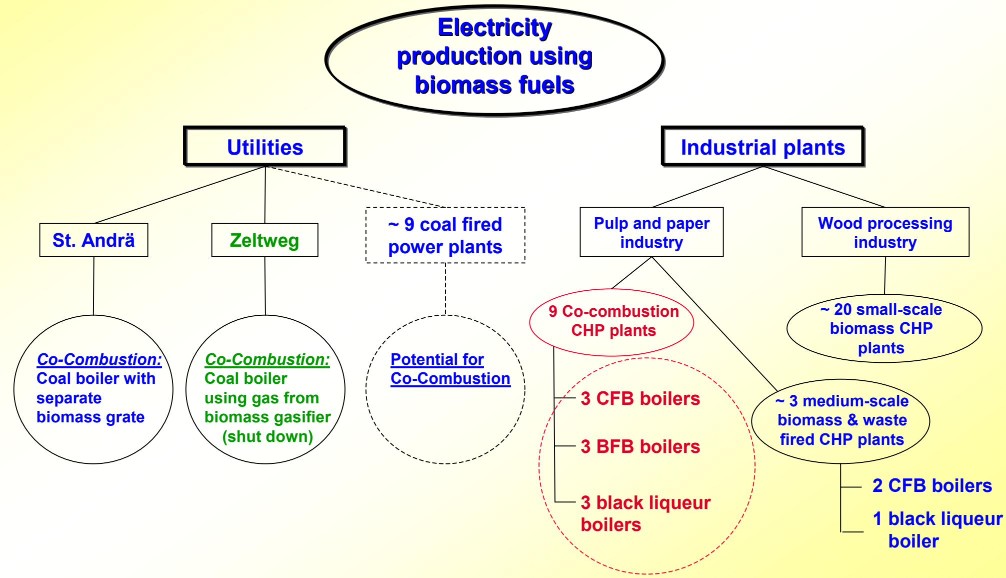
Challenges of biomass co-firing

- Risk of ash deposition problems
- Risk of high-temperature corrosion
- Problems regarding the deactivation of SCR catalysts
- Reduced ash disposal / utilisation options
- Increase in carbon carryover or unburned carbon
- Problems regarding biomass fuel supply may occur
- An increase of the fuel costs can occur
- Substantial increase in volumetric feeding and fuel storage areas
- Thermal biomass utilisation in decentralised plants is perhaps more effective regarding the limited resources of biomass fuels available

Electricity production using biomass fuels in Austria (1)



Electricity production using biomass fuels in Austria (2)

	GWh_{el}/a from biomass fuels
Utilities	
St. Andrä	~ 7.5
Zeltweg (shut down)	(~ 5)
~ 9 coal fired power plants (potential for co-combustion)	~ 500
Industrial plants	
Wood processing industry	
~ 20 small-scale biomass CHP plants	~ 100
Pulp and paper industry	
~ 3 medium-scale biomass & waste fired CHP plants	~ 300
9 co-combustion CHP plants	~ 1,000

- Total electricity production in Austria: ~50,000 GWh_{el}/a
- Electricity production from thermal power plants in Austria: ~14,000 GWh_{el}/a

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Methodology

Description of the different co-firing technologies according to the following evaluation criteria:

- Operating principle
- Influence of the biomass fuel on the overall system
- State of development and experiences already achieved
- Electricity production costs
  (calculation of the electricity production costs according to the guideline VDI 2067)

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Technologies for co-firing biomass with fossil fuels

- Biomass co-firing in existing pulverised coal combustion (PCC) systems
  - Co-firing of biomass on a separate grate directly under the coal boiler
  - Co-firing of finely milled biomass mingled with coal
  - Co-firing of finely milled biomass by separate injection
- Biomass co-firing in fluidised bed combustion (CFB and BFB) systems
- Biomass co-firing by using separate combustion units and junction of steam
- Biomass gasification and utilisation of the product gas as fuel in a coal combustion system

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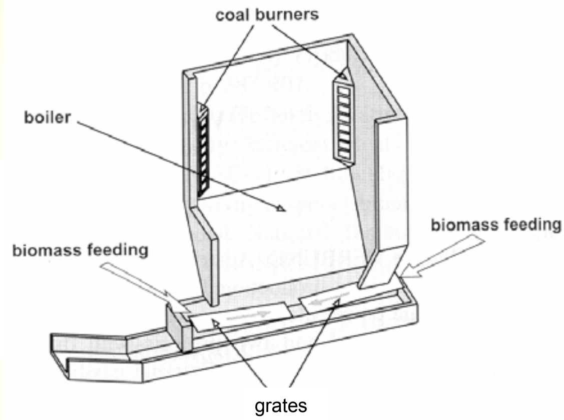
Co-firing of biomass on a separate grate directly under the coal boiler

+ Large variety of biomass fuels to be used (especially regarding particle size and water content)
+ High biomass and coal carbon conversion
- Limited applicability due to space available under the boiler
- Mingled biomass and coal bottom and fly ash



Austrian application: St. Andrä

- Nominal capacity 124 MW_{el} / 284 MW_{th}
- Biomass contribution 3 % of the fuel input (NCV)

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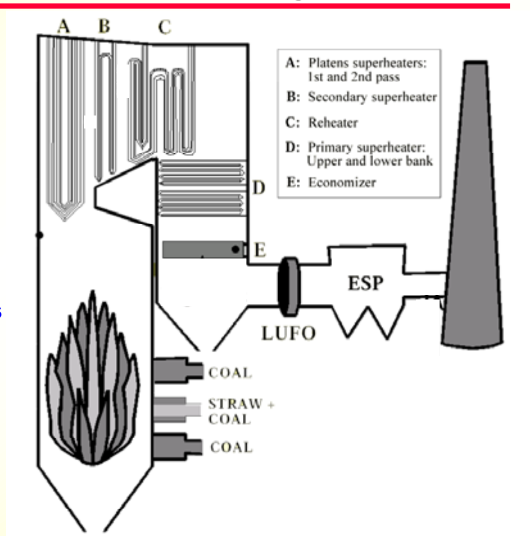
Co-firing of finely milled biomass mingled with coal

+ No significant modifications are necessary
- Particle size < 3 mm
- Water content < 30 wt.% (w.b.)
- Pneumatic delivering system of the fuel to the burner is necessary
- Corrosion and deposition problems (especially when co-firing straw)
- Deactivation of $DeNO_x$ catalysts
- Plugging and bridging problems
- Ash utilisation problems



Applications in operation in DK, FIN, NL and USA

Co-firing of finely milled biomass by separate injection

Advantages and disadvantages of separate injection compared to mingled biomass and coal:

+ Optimised biomass handling and preparation due to separate storage
+ Better burner optimisation to the biomass fuel possible
+ Increased fuel flexibility
+ Increased biomass loading
- Increased capital costs
- Formation of stratified flows

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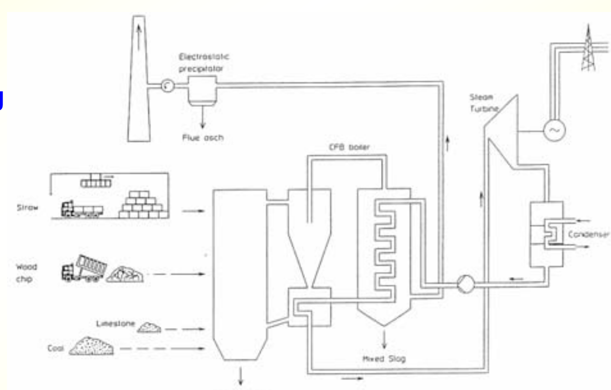
Biomass Co-firing in CFB and BFB combustion systems

+ Utilisation of biomass with higher particle size possible
+ High flexibility concerning utilisation of biomass fuels
- Higher risk of bed agglomeration and fouling
- Separate feeding systems for each fuel
- Mixture of coal and biomass ashes



Applications in operation in A, DK, S, FIN, NL and USA

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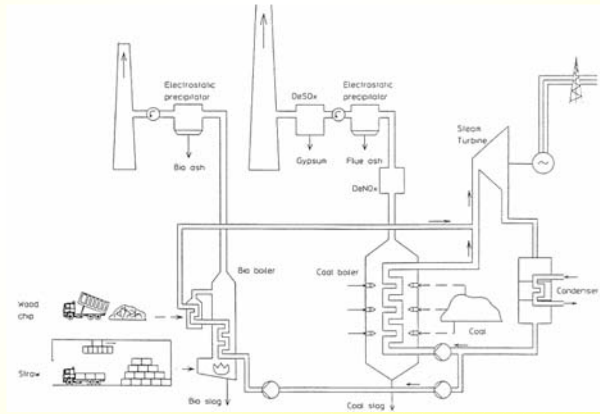
Biomass co-firing by using separate combustion units and junction of steam

- \+ Best adjustment of the boiler and the flue gas cleaning system to the fuels used
- \+ Separate utilisation of biomass and coal ashes
- \+ Higher steam parameters are possible
- \+ Smaller operating costs
- \- Higher investment costs
- \- More complex plant design



2 applications in operation in DK

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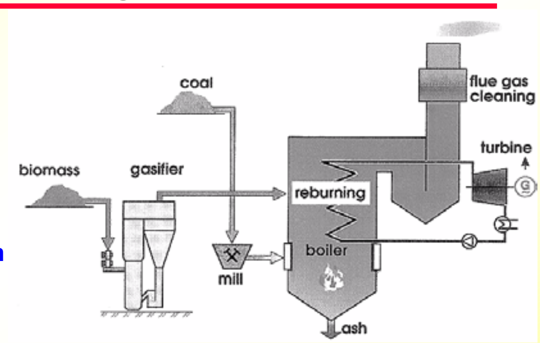
Biomass gasification and utilisation of the product gas as fuel in a PCC unit

- \+ No fuel pre-drying
- \+ Particle size up to 40 mm
- \+ No special demands on the gas
- \+ NO_x reduction by fuel staging possible
- \+ High flexibility concerning utilisation of biomass fuels
- \+ Easy application to existing coal-fired power plants
- \- Higher capital costs
- \- More complex plant design and operation
- \- Biomass and coal fly ashes are partially mixed



Austrian application: Zeltweg

- Nominal capacity 137 MW_{el} / 330 MW_{th}
- Biomass contribution 3 % of the fuel input (NCV)

Finnish application: Kymijärvi

- Nominal electric capacity 167 Mw_{el}
- Thermal capacity biomass gasifier 40 – 70 MW (depending on the fuel input)

Economics – framework conditions (1)

- **Calculations are based on additional electricity production from biomass → only the additional costs for power production have to be considered**
- **Economic calculations performed according to VDI guideline 2067**
- **Data gained from comprehensive investigations performed in Austrian wood processing industries and utilities as well as from plant owners.**

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Economics – framework conditions (2)

Technology			1	2	3	4	5	6	7
Technical data biomass co-firing									
Nominal thermal capacity	P_{th}	MW_{th}	70	100	100	100	100	10	10
Gross electric capacity	P_{el}	MW_{el}	28	40	40	40	40	4.2	4.1
Full load operating hours	t_{FL}	h p.a.	3,000	3,000	3,000	3,000	3,000	3,000	3,000
Specific internal electricity consumption		kW_{el}/MW_{th}	8	40	5	5	11	8	11
Investment costs									
Technical installations		1,000 €	8,000	8,700	700	17,000	7,300	500	2,300
Conveying system		1,000 €	2,300	4,400	2,500	2,500	2,500	600	600
Construction work (storage, base plate)		1,000 €	700	1,100	400	1,100	900	200	300
Control system		1,000 €	200	600	100	400	400	100	300
Total investment costs	I	1,000 €	11,200	14,800	3,700	21,000	11,100	1,400	3,500
Spezific investment costs	I / P_{el}	$€/kW_{el}$	400	370	93	525	278	333	854

1...Biomass grate
2...Co-firing in PCC plant
3...Co-firing CFB
4...Separate biomass boiler
5...Biomass gasification
6...separate biomass grate (pilot plant St. Andrä)
7...biomass gasification (pilot plant Zeltweg)

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Economics – framework conditions (3)

Technology		1	2	3	4	5	6	7
Electricity production costs of the biomass co-firing unit								
Capital costs								
Interest rate (real)	% p.a.	7	7	7	7	7	7	7
Lifetime co-firing unit	a	8	8	8	8	8	8	8
Consumption based costs								
Fuel price	€/MWh_{NCV}	15	15	15	15	15	15	15
Material costs at t_{FL} = 8760 h/a	(% of I) p.a.	0.5	0.5	1.0	1.0	1.0	0.5	0.5
Operation based costs								
Personal costs per hour	€/h	22	22	22	22	22	22	22
Working hours at t_{FL} = 8760 h/a	(% of 8760h) p.a.	30	70	35	45	35	10	15
Maintenance costs at t_{FL} = 8760 h/a	(% of I) p.a.	1.5	3.5	1.7	1.7	2.2	1.5	1.5
Other costs								
Administration, inssurance	(% of I) p.a.	2.0	2.0	2.0	2.0	2.0	1.5	1.5

1...Biomass grate
2...Co-firing in PCC plant
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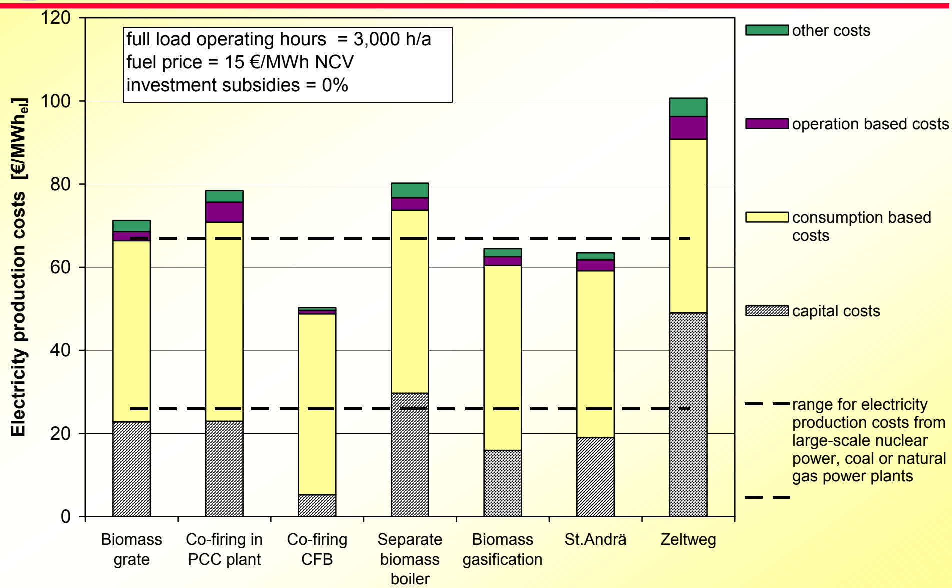
Economics – electricity production costs



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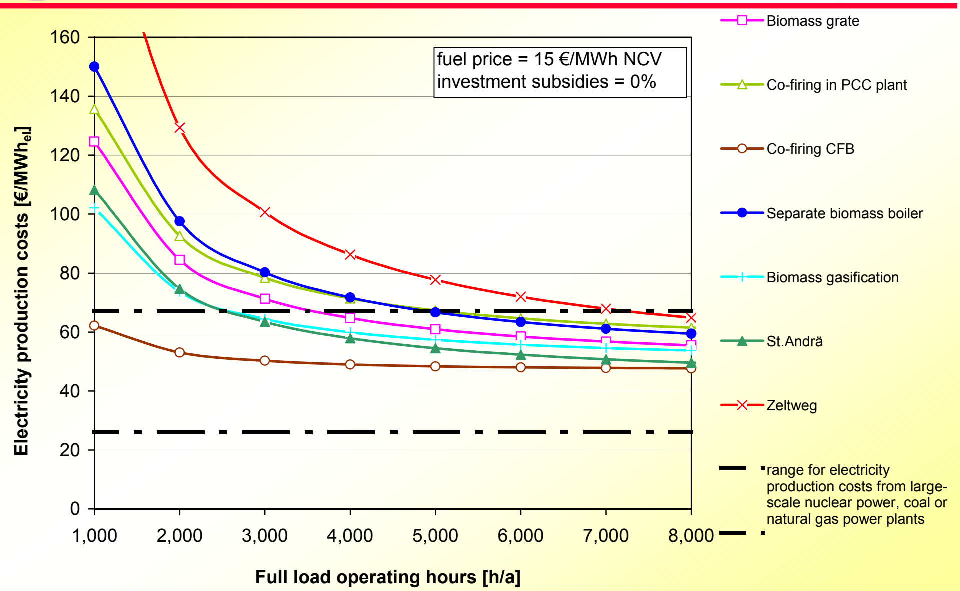
Economics – sensitivity analysis electricity production costs vs. full load operating hours



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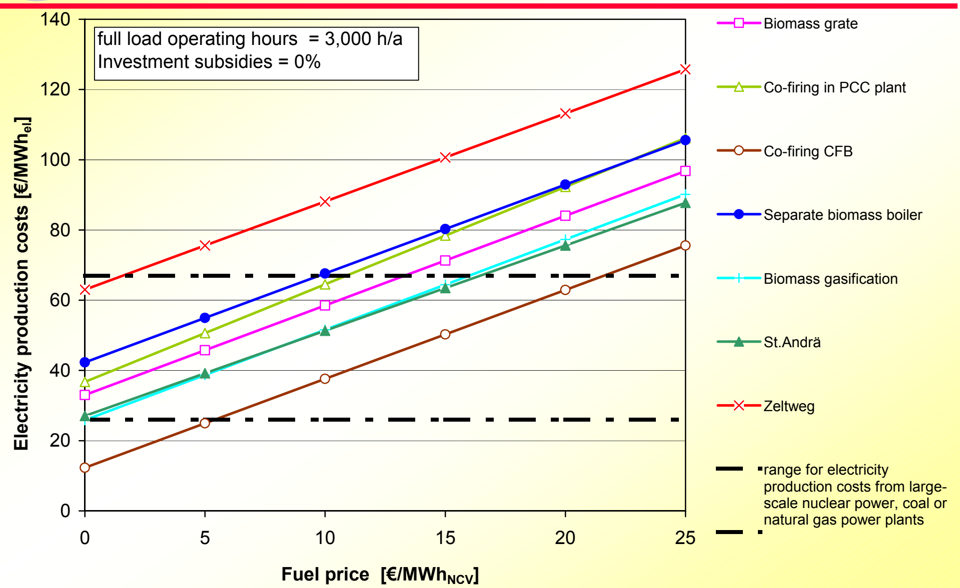
Economics – sensitivity analysis electricity production costs vs. fuel price



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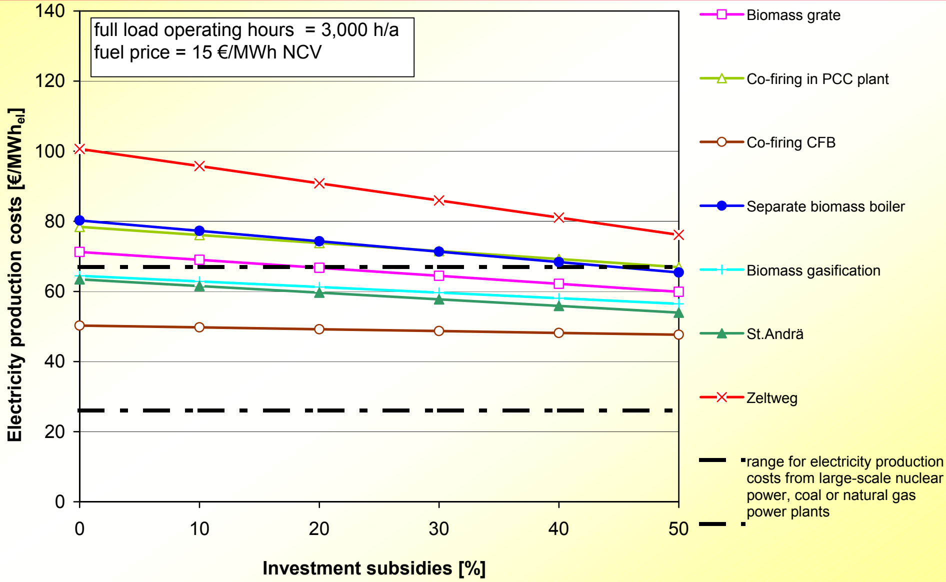
Economics – sensitivity analysis electricity production costs vs. investment subsidies



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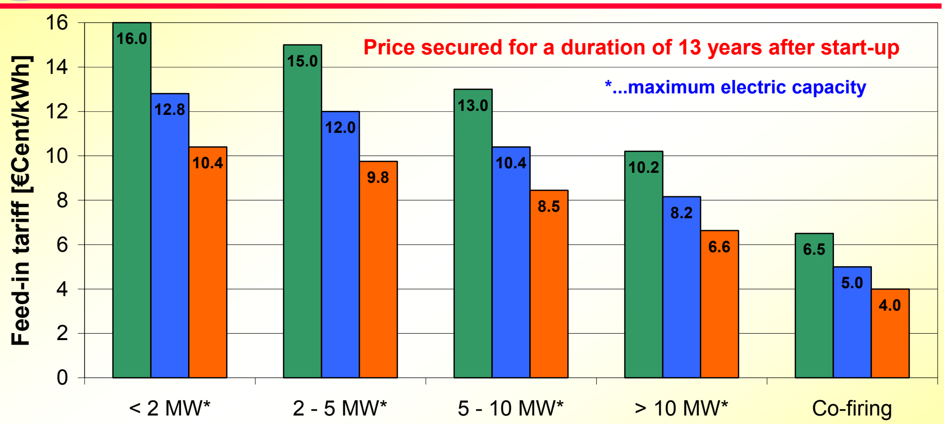
Austrian feed-in tariffs for electricity production from solid biomass



Forestry wood chips

Primary energy source according to Table 2 in the annex to § 5 (1) 5 of the Austrian Electricity Supply Act, e.g. by-products from sawmills

Primary energy source according to Table 1 in the annex to § 5 (1) 5 of the Austrian Electricity Supply Act, e.g. waste wood

Summary (1)

- Co-firing has a high short-term potential for electricity production from biomass and therefore for a substantial reduction of CO_2 emissions
  (due to large plant capacities of existing power plants)
- Several proven co-firing technologies are available
- Technical barriers can be surmounted by proper attention to boiler design, boiler operation and fuel properties
- Usually NO_x and SO_x reduction when using pure wood fuels
- Problems concerning deposition, erosion and corrosion in boilers need additional and critical research

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Summary (2)

- Most importantly biomass-coal co-firing using biomass residues as a feedstock represents possibly the lowest cost and lowest risk option (for increased renewable energy production)
- Electricity production costs for the different large-scale co-firing technologies considered are between 50 and 80 €/MWh_{el} (54 – 86 US$/$MWh_{el}$)
- Biomass co-firing with coal is slightly more economically favourable than power production in large-scale biomass CHP plants (electricity production costs 70 to 100 EUR / MWh_{el}).

Summary (3)

- The economy of biomass co-combustion plants is strongly influenced by the annual full load operating hours that can be achieved (> 3.000 h/a are necessary) and by the fuel price (price target: 15 €/MWh_{NCV} (16 US$/$MWh_{NCV}$) and lower)
- Increased and secured feed-in tariffs for electricity from biomass co-combustion plants strongly support this technology
(e.g. regulated in the new Austrian regulation for electricity production from renewables)