Biomass co-firing

Status in The Netherlands

Ronald Meijer

Product manager co-firing

KEMA Power Generation & Sustainables

Co-firing driving forces

- Renewable targets
- Lowering of CO_2- emissions from fossil power stations
- Covenant with the Dutch government
- Stimulation by the authorities (MEP)
- Lowering of fuel costs
- Lowest investment cost per kW_e installed
- High efficient conversion to electricity

Co-firing biomass in the Netherlands

- Since 1993 more than 40 small and full scale trials co-firing up to 40 wt% of a wide variety of biomass and waste fuels with coal.

- Currently experience up to 10^{+} wt% co-firing
- Co-firing is daily practice in all Dutch coal-fired power plants

- **up to 2008: realization of the coal covenant. Implies > 20 wt% co-firing**

Coal Covenant of May 2002

- 3.3 Mton CO_2 reduction by co-firing biomass in coal fired power stations
- equals 475 MW_e installed capacity
- 12 % replacement of coal (heat) input
- requiring ~ 2.2 Mton of biomass/waste per year

Must be accomplished in 2008

KEMA

Co-firing in the Netherlands

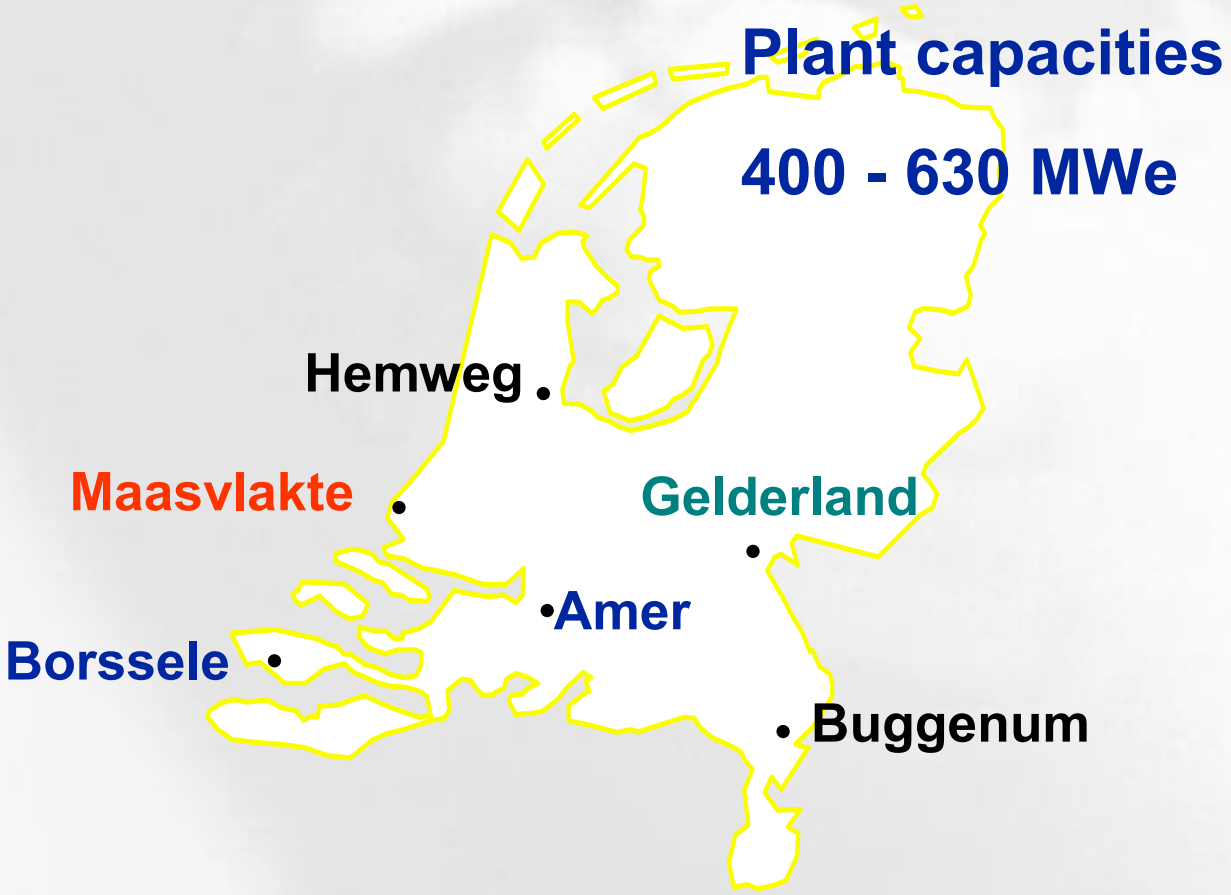
Electrabel

E.On Benelux

NUON Power

Generation

Essent



Installed coal-fired capacity 4000 MW_e

Mass Balance Measurements during Co-firing of Biomass, Secondary Fuel or Waste

Test series #	date	Plant and unit [2)]	Plant capacity in MW_e	Origin of coal	co-combustion material	co-combustion dry amount mass %
*	1993	KTB[1)]	1	Australia	demolition wood v1	4.5, 9.2, 12.9
I*	1993	KTB	1	Australia	demolition wood v2	9.7
II*	1994	KTB	1	Colombia	demolition wood x1	4.6, 8.6, 13.0
V*	1994	KTB	1	Colombia	demolition wood x2	8.1
*	1994	KTB	1	Colombia	demolition wood x3	9.2
VI*	1994	KTB	1	Colombia	sewage sludge	4.8, 7.6, 10.3
VII*	1995	KTB	1	USA	petcokes	4, 8, 12, 12.2

Positive results have led to successful introduction of co-firing in all Dutch coal-fired power plants

KTB = KEMA Test Boiler

Mass Balance Measurements during Co-firing of Biomass, Secondary Fuel or Waste

Test series #	date	Plant and unit [2)]	Plant capacity in MW_e	Origin of coal	co-combustion material	co-combustion dry amount mass %
VIII*	1995	MV-2	518	Blend	petcokes	5-9
IX*	1995	HW-8	600	Blend	sewage sludge	3, 6
X*	1995-12	AC-8	600	Blend	paper sludge	5, 8
XI*	1995	AC-9	600	Blend	petcokes A	5, 10
XII*	1995	AC-9	600	Blend	petcokes B	5, 10
XIII	1996	BS-12	403	Colombia	hydrocarbon gas (P)	3 [3)]
XIV*	1996	MV-2	518	Blend	petcokes A	5, 10
XV*	1996	MV-2	518	Blend	petcokes B	5, 10
XVI	1997	MV-2	518	Blend	biomass pellets	5
XVII*	1997-3	CG-13	600	Blend	demolition wood	5, 10
XVIII	1998-3	AC-9	600	Blend	paper sludge	5
XIX	1998-9	MV-2	518	Blend	biomass/citrus	8.5
XX*	1998-10	BS-12	403	Poland	sewage sludge	5, 9
XXI	1998-12	BS-12	403	Blend	paper sludge	5
XXII*	1998/9 /11	KTB	1	Venezuela	municipal waste (plastic fraction)	5, 10
XXIII	1999-9	MV-1	518	Blend	coffee grounds	3
XXIV	1999/11	BS-12	403	Blend	cacao shells	9
XXV	1999/11	MV-1	518	Blend	poultry dung	3

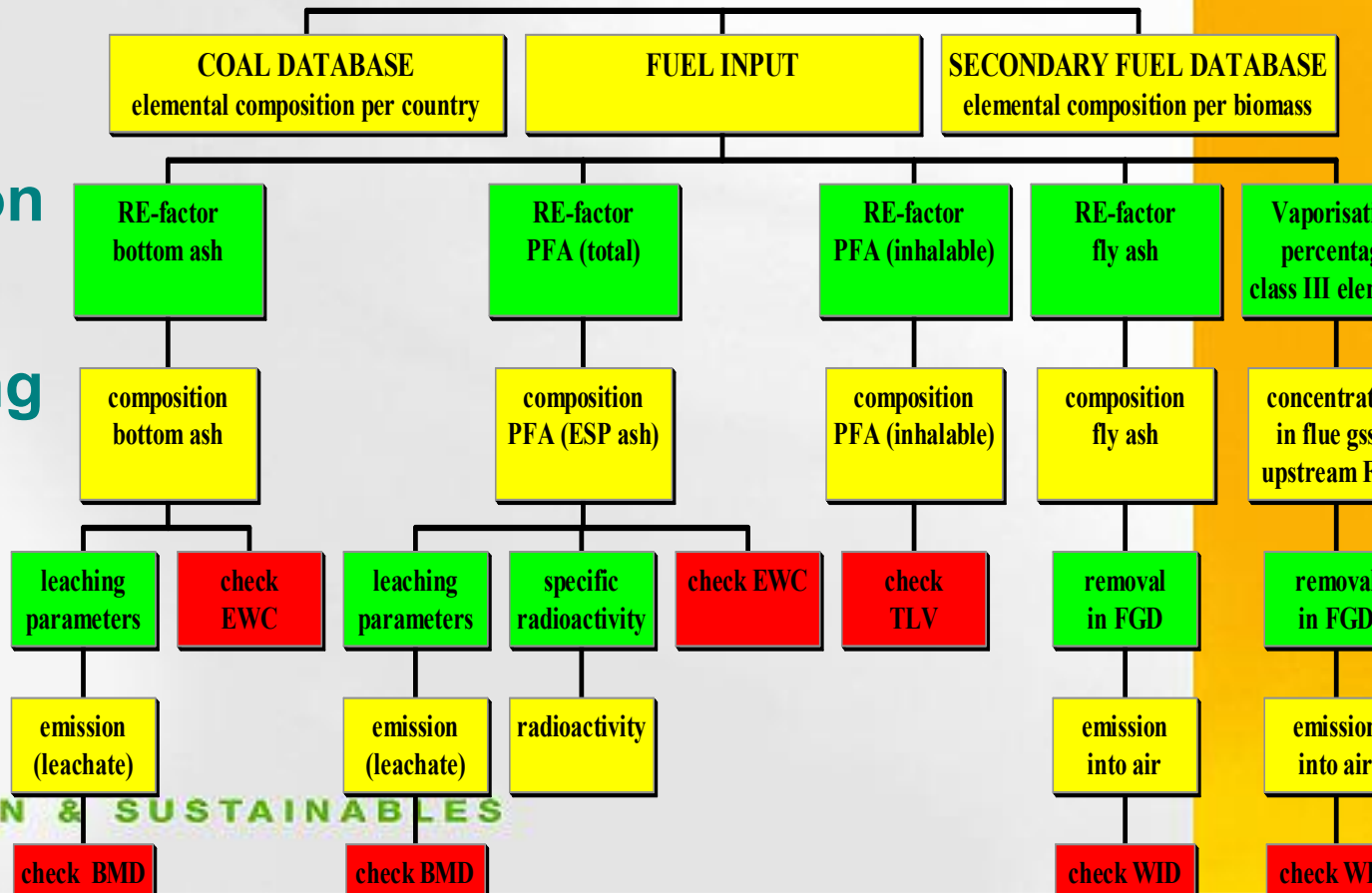
Co-Combustion

KEMA TRACE Model ®

Validated model for determining the fate of trace elements and emissions during (in)direct co-firing in full scale coal fired and stand alone CFB biomass gasification and combustion power plants.

Output

- Impact of fuel composition on ash quality
- Maximum allowed co-firing percentage in relation to by-product quality and emission legislation



Mass Balance Measurements during Co-firing of Biomass, Secondary Fuel or Waste

Test series # [1]	date	Plant and unit [2]	Plant capacity in MW_e	Origin of coal	co-combustion material	co-combustion dry amount mass %
XXVII*	2001-1	KTB	1	Venezuela	poultry dung	24, 34, 39
XXVIII*	2001-1	KTB	1	Venezuela	waste wood	16, 30, 42
XXIX*	2001-1	KTB	1	Venezuela	RDF	14, 28, 34
XXX*	2001-4	MV-1	518	Blend	meat and bone meal	2.7
XXXI*	2001-6	MV-1	518	Blend	meat and bone meal	2,2
XXXII*	2001-8	MV-1	518	Blend	meat and bone meal	5,1
XXXIII*	2001-11	AC-9	600	Blend	fresh wood	7
XXXIV	2001-11	MV-1	518	Blend	biomass blend	16
XXXV	2002-1	MV-2	518	Blend	biomass blend	15
XXXVI*	2002-4	BS-12	403	Blend	wood+paper sludge	±10,9
XXXVII*	2002-11	BS-12	403	Blend	ONF+biomass	11,5
XXXVI	2002	AC-9	600	Blend	wood pellets	33
XXXIX	2003	MV-1	518	Blend	M&B meal+biomass	>10

KTB = KEMA Test Boiler

Co-Combustion

Co-firing - Dutch experiences

Biomass pellets	(Dried) sewage sludge
(Waste) wood	Fluids
Paper sludge	Char coal
Cocoa shells	Wood pellets
Industrial gases	Meat and bone meal
Chicken litter	ONF, RDF, plastics
Imported fuels	Olive kernels

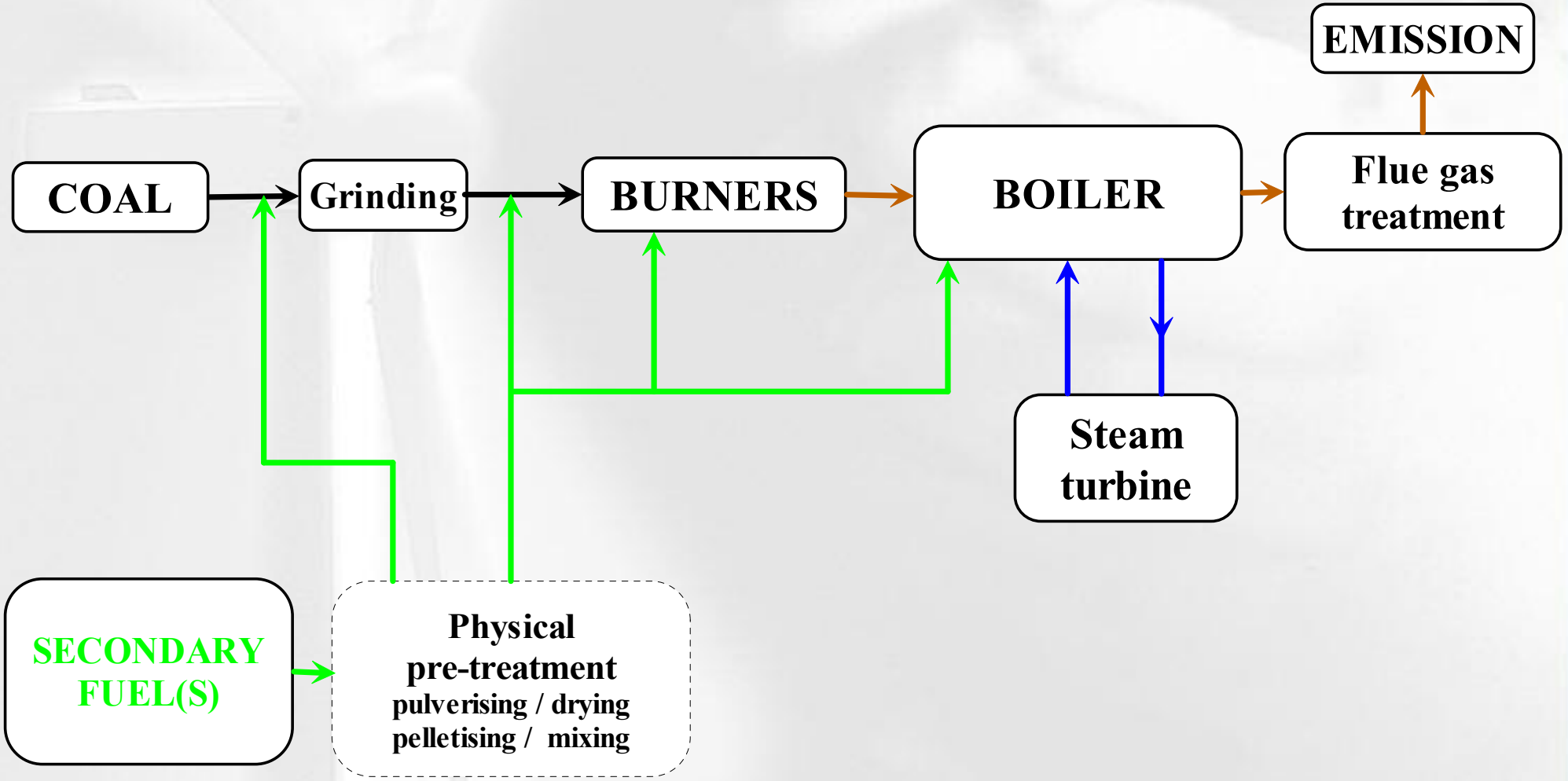
up to 10^{+} mass% (Dutch power plants)

up to 40 mass% (KEMA 1 MW_{th} plant)

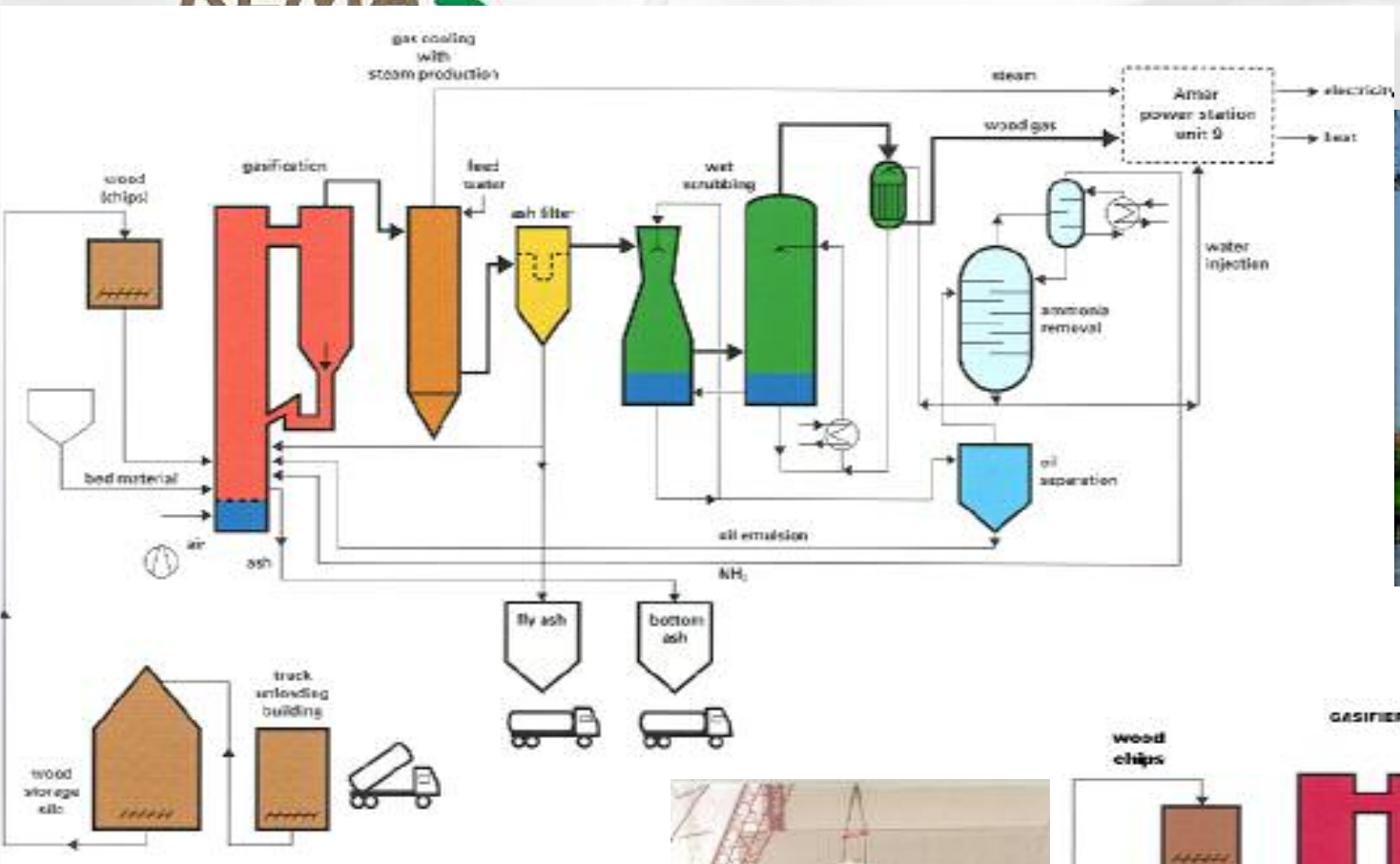
Co-firing - Technical constraints

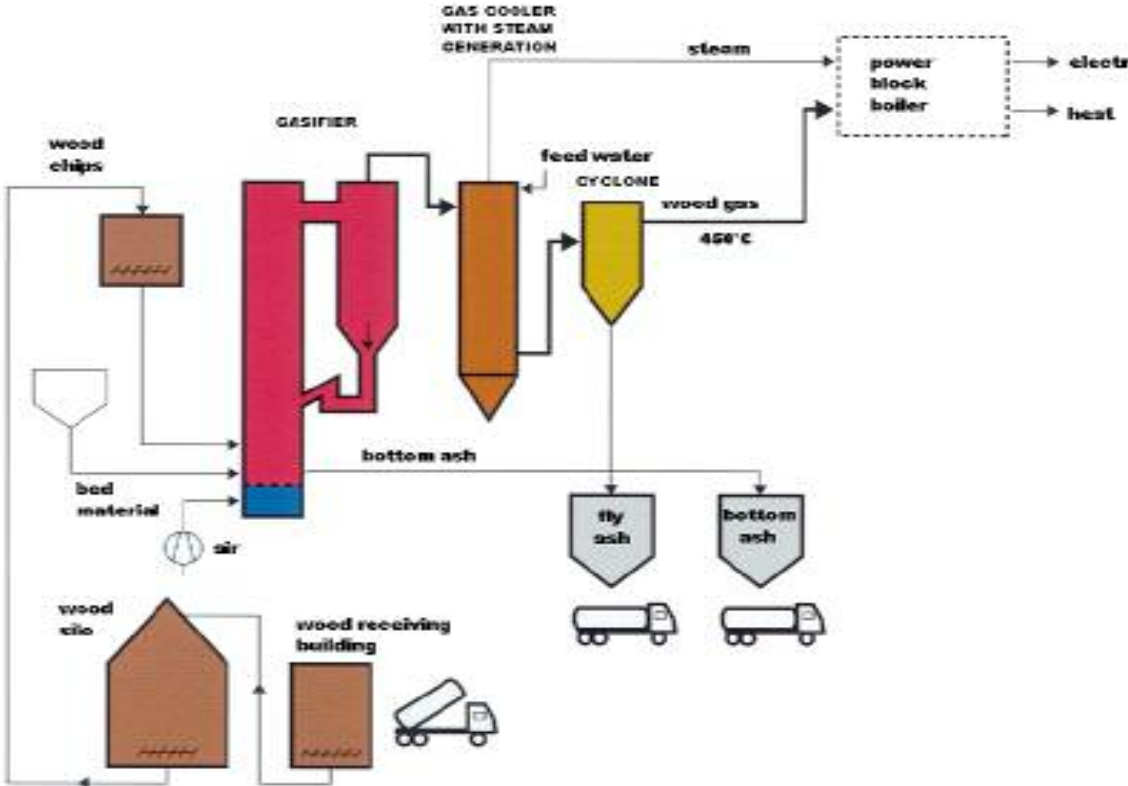
- Grindability, capacity of the unit operations
- Slagging, fouling, corrosion, erosion
- Effect on fuel gas equipment (FGD + SCR)
- Occupational health and safety aspects
- Emissions
- Quality of the ashes
- Load following behavior, (un)availability
- Heat balance, efficiency
- Integration

Routes applied for direct co-firing



Amer-9 wood gasifier





CFB gasifier

- waste wood
- 83 MWth input
- 170 kton CO_2 red

KEMA POWER GENE

Co-gasification in IGCC

- Target: conversion to fuel mix of 50% biomass and 50% coal producing 60 MW green power at total output of 200 MW

- Sewage sludge, chicken litter, wood

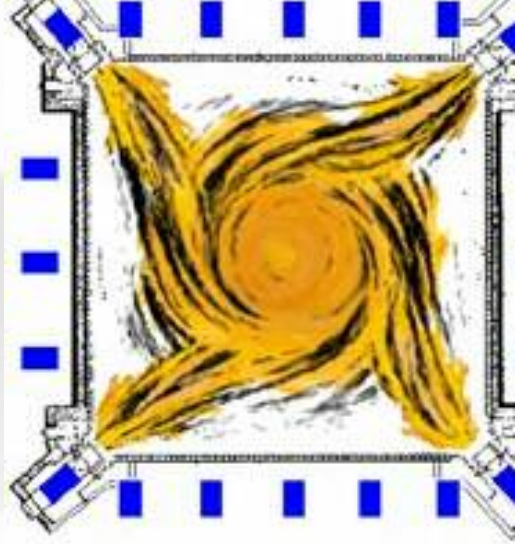
250 MW_e Integrated Coal Gasification Combined Cycle plant, Willem Alexander Centrale

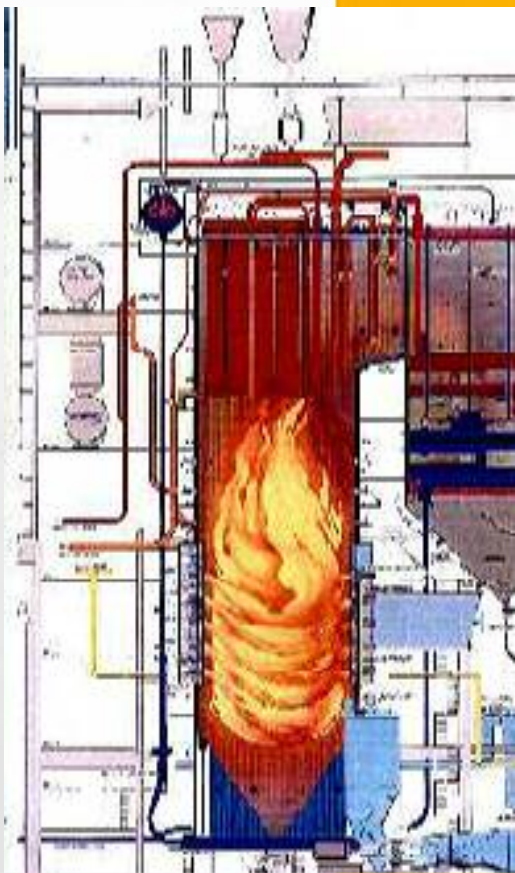
Potential dangers for the main boiler

- Slagging and fouling by biomass ash
- Corrosion by HCl near gas burners
- Heavy metals corrosion
- NO_x formation in boiler
- Increased Hg content in gypsum
- Poisoning of SCR catalyst
- Exceeding of emission limits
- Contamination of coal ash with biomass ash

Co-firing - Current issues

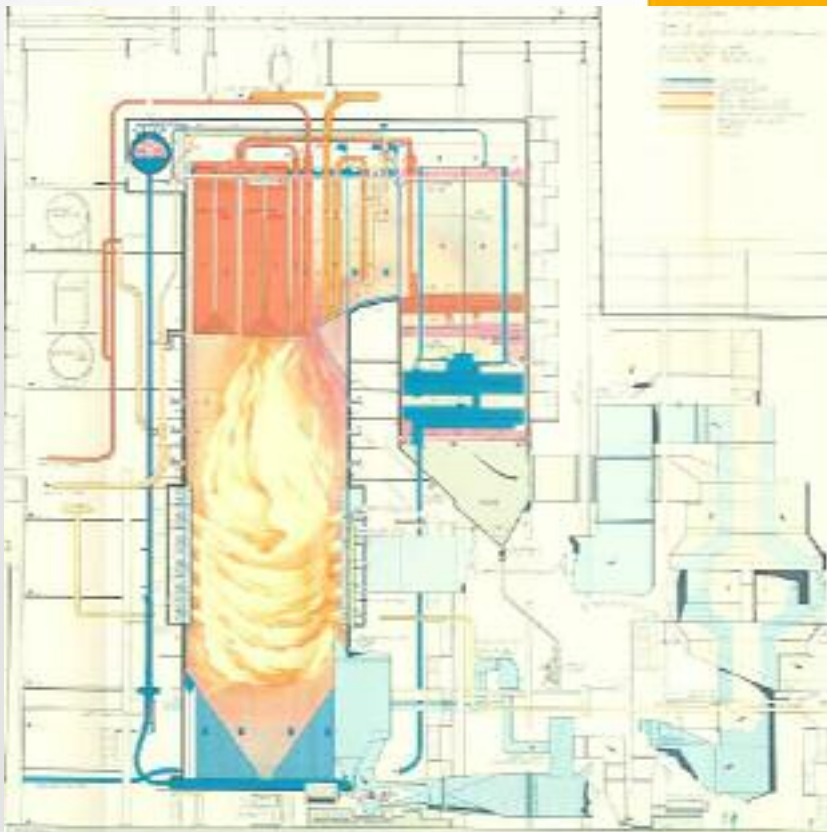
- Permits
- The quality of biomass
- Fuel flexibility and pre-treatment
- Maximizing co-firing
- Thermal behavior and efficiency
- Environmental constraints - emissions
- Quality and applicability of by-products
- Integration, optimization
- Economics





Co-firing status in Netherlands

- Direct co-firing up to 10 wt% daily practice
- Next steps
  - direct co-firing > 20 wt%
  - indirect co-firing (CFB)



Key factors for co-firing projects

- Acceptance by the government and public
- Permits

- Economics

- Environmentally sound
- Technically feasible

KEMA POWER GENERATION & SUSTAINABLES

Super critical power plants

- Super critical power plants also help to reach CO_2 targets
- Super Critical Power Plant in The Netherlands since 1970 (gas fired) and 1980 (coal fired)
- Plant conditions: 1000/1050F/3900Psi
- EU Ultra Super Critical Power Plant project (USC Thermie) 1300 F/5400Psi
- Efficiency 52%

PLANT	OUTPUT (MWE)	η-NET (LHV) %
Claus A+B	2* 640	40
Hemweg 8	630	43
Amer 9	600	42.5