NOx abatement in Swedish large and medium sized combustion plants - fuelled with biomass, - or used for co-incineration for energy production

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mg/MJ!

Multiply mg/MJ with

2,5 (for biomass with 50 % moisture), or
2,8 (for biomass with 20 % moisture)

to get mg/Nm^3 at 6 % O_2

Mutiply mg/MJ with

1,8 (for biomass with 30 % moisture)

to get mg/Nm^3 at 11 % O_2

Summary

- In combustion & co-incineration plants (in the Swedish Energy and Industrial Sectors) biomass and biomass waste predominate
- Primary measures to abate NOx are frequent and sophisticated
- For biomass combustiong & co-incineration for energy production:
  - ~ 150 units have SNCR
    - – Typically 50 - 120 mg/MJ with SNCR
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  - 7 - 10 have Slip SCR (as high dust) in combination with SNCR

Combustion Plants in Sweden

- *Units = mostly boilers (and some gas turbines)*
- *Plants = all the units at the site*
- ~ 700 combustion plants EU ETS
  ~ 430 units Swedish "NOx Charge"
- ~ 140 LCP plants (with ? 300 units)
  ~ 80 WID plants (with 135 units)

- Major product = Heat for district heating: 50 - 60 TWh annually
  - + Power at CHPs & Industry: ~ 14 TWh
  - + Steam at Industry: 10 TWh
  - + District cooling: ~ 1 TWh
  - + Condensed Power: ~ 0,3 TWh

Energy Statistics Sweden

Energy Sector:

- 400+ district heating nets
- ~ 70 CHP plants with 10 TWh power production
- 70 TWh thermal input for heat and CHP:
  - ~ 40 % biomass + ~ 25 % waste
  - ~ 9 % fossil + ~ 4 % peat
  - ~6 % flue gas condensation

Industry Sector:

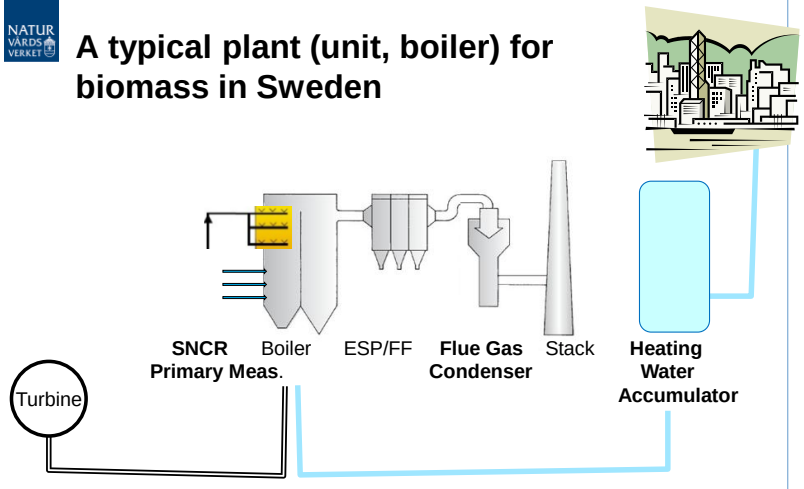
- 15 TWh biomass for steam and power production in:
  - Pulp & Paper (10 TWh excluding recovery boilers)
  - Saw Mills (4 TWh)

Typical plant in the Energy Sector in Sweden - Today

Example:

- Boiler 4 - CHP - 2007 - base load - "co-incineration plant"
  - » waste wood and other waste fuels
  - » some virgin wood
- Boiler 3 - CHP - 1984 - mid meritt - built for coal, but retrofitted to wood chips
- Boiler 2 - Heating Water - 1971 - peak load - bio oil
- Boiler 1 - Heating Water - 1966 - reserve load - gas oil

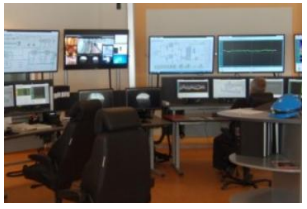
A typical plant (unit, boiler) for biomass in Sweden



Primary measures at biomass boilers in Swede

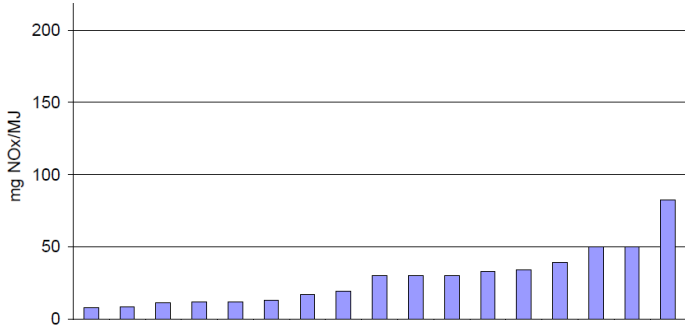
Primary measures important Role

Together with hour to hour focus



- Staged combustion, of course
  - Including
    - Rotating Over Fire Air
    - Ecotube
    - .....
- Recirculation of Flue Gas
- Injection of water or steam in boiler
- Cooling of combustion air
- Sulphur injection
- ... and others

NOx Yearly average at those biomass and waste fired boilers which have SCR



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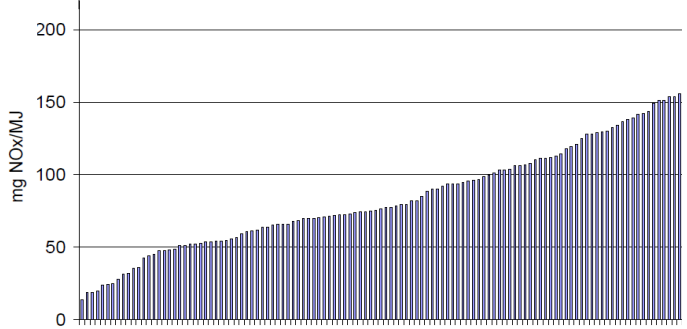


SNCR vs SCR for new biomass and co-incineration boilers

- Above 40 mg/MJ SNCR is first choice
  - since economy is determining factor
- Below 40 mg/MJ SCR is probably the best option,
  - or for lower levels: the only choice

Estimated Costs for 75 MW_{th} Biomass Boiler

	Investment	***Ammonia***	***Catalyst***
• SCR	5 million €		Deactivation Rate critical
• SNCR	1 million €	2-3 times more than SCR	---

Estimated annual Costs in € per kg NOx

	Cost	*Being installed at (*)*
• Primary measures	1 - 2	all units more or less
• SNCR	1,5 - 3	~ 150 units
• SCR	4 - 20	1 unit 10 units (slip-SCR)

Calculation method:

- Depreciation during:
  - 10 years for primary measures and SNCR
  - and 20 years for SCR
- Interest rate 10 % (!!)

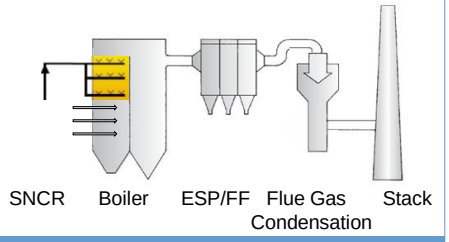
(*) = biomass and co-incineration

SNCR
- at biomass and co-incineration boilers

- Yearly averages range from 13 to 150 mg/MJ thermal input
  - 70 % of units: **50 - 120 mg/MJ** yearly average
  - Upper end of interval quite high
    - – Existing boilers have been retrofitted

~ 150 units (i.e. boilers) in Sweden today have SNCR

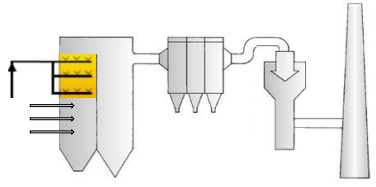
~120 with ammonia
~ 25 with urea
~ 8 with ammonium sulphate



SNCR

Conditions that must be fulfilled :

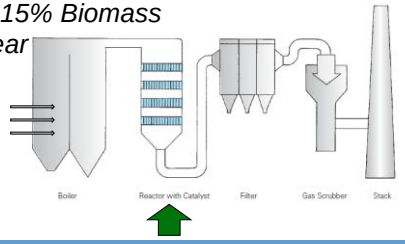
- Temperature levels
- Reaction times
- Injection at several levels
- NH_3 slip



High Dust SCR
- at biomass and co-incineration boilers

- Beginning af the 90:s: Some coal boilers converted to biomass
  Catalysts removed or now used as slip-SCR
- Biomass & Tyres/ Recycled wood/ Paper&Plastics
  Deactivation ~ 50 % per year
  1993-2000 Norrköping, 1994 - 2004 Nyköping
- *Coal co-combusted with 10-15% Biomass*
  Deactivation 10-20 % per year
  DK, NL, ...

☹



SNCR and Slip SCR in High dust position
- at biomass and co-incineration boilers

- Installed at ~ 6 biomass plants since 1997
  - 15 - 55 mg/MJ
- ~ 8 - 20 % deactivation per year
  - Catalyst elements exchanged after 3 - 7 years

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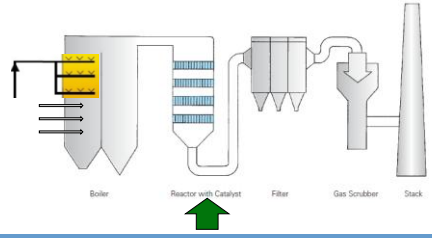
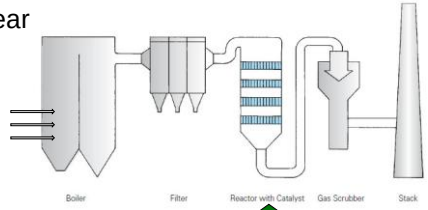


Low Dust SCR - after dust abatement - at biomass and co-incineration boilers

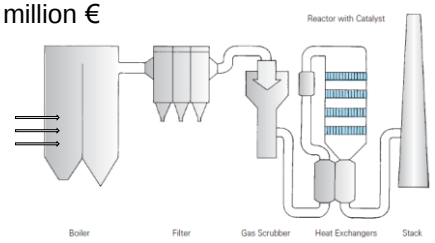
Only few installations:

- % Bio and % Peat
  since 2010 - Umeå
  15 mg/MJ yearly average
- 50 % Bio and 50 % Peat
  Deactivation <10 % per year
  1994-2000 Kiruna



Tail End - at biomass and co-incineration boilers

- Waste incineration plants: Dominating
  - Deactivation ~ 1-3 % per year
- (As far as we know) Not used in Sweden for pure biomass
- Heat exchanger cost ~ 1 million €
- Nead of net extra energy
  + 1-2 MW
  for a 75 MWth boiler



Summary - *Once again!* ☺

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Thank you for your attention

And a special thank to:
- The colleagues at the Administration of the NOx Charge
- The Swedish Thermal Engineering Research Institute ("Värmeforsk")

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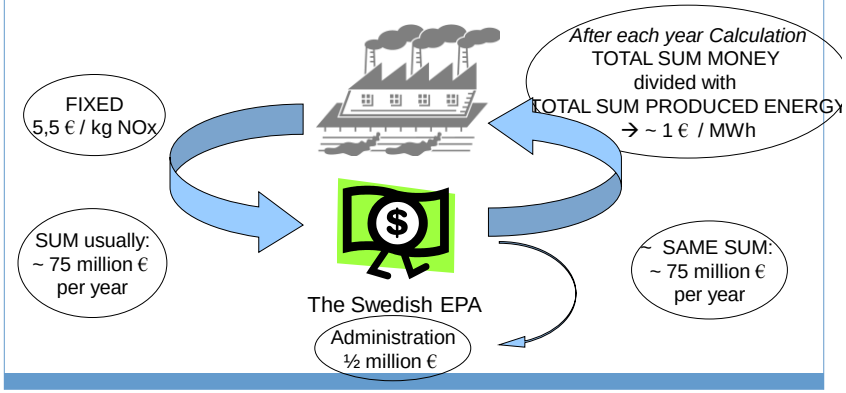
The Swedish Charge on NO_X

Some extra slides

The Swedish Charge on NO_X

Applies to boilers & gas turbines for energy production with Energy production > 25 GWh per year



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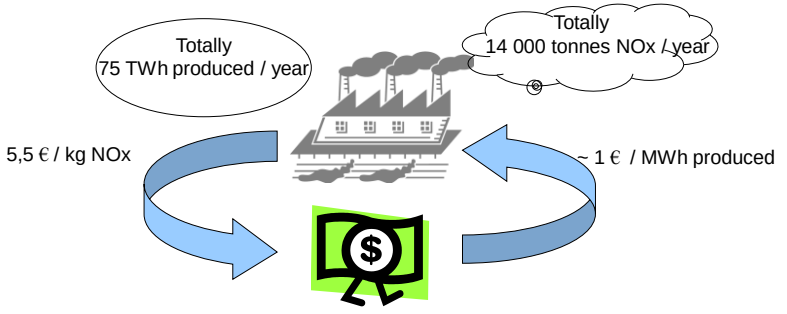
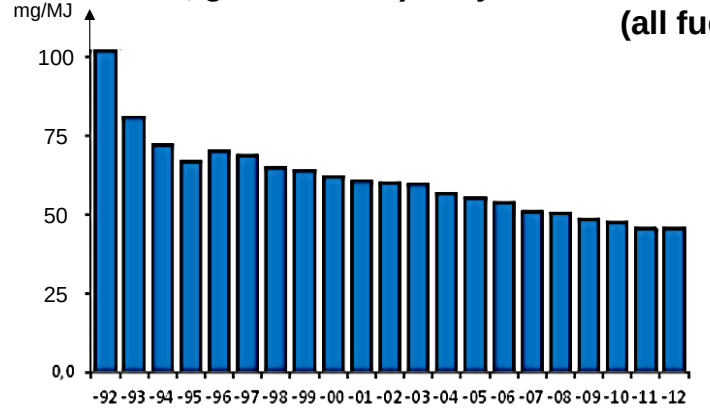
Applies to boilers & gas turbines for energy production with Energy production > 25 GWh per year



Benchmark "automatically" set by the performance of all plants

0,41 kg/$MWh_{produced}$ in 1992 → 0,18 kg/$MWh_{produced}$ in 2013

Yearly average NO_X emissions for all units (boilers, gas turbines) subject to NOx Charge (all fuels)



Why the NOx Charge have been successful

- High charge level (5,5 € per kg)
- Every kilogram counts
  - →Focus at NOx levels from hour to hour by personnel for operation of the plant
- Measures for decreasing emissions are taken at plants where the cost is least
- Reduced effect on competition due to the refund construction
- Technology development
- Winners and losers in every sector → Rather well received
- Very low administration cost (<1%)

Net yearly economic result for all ~ 400 boilers - individually under the NOx charge