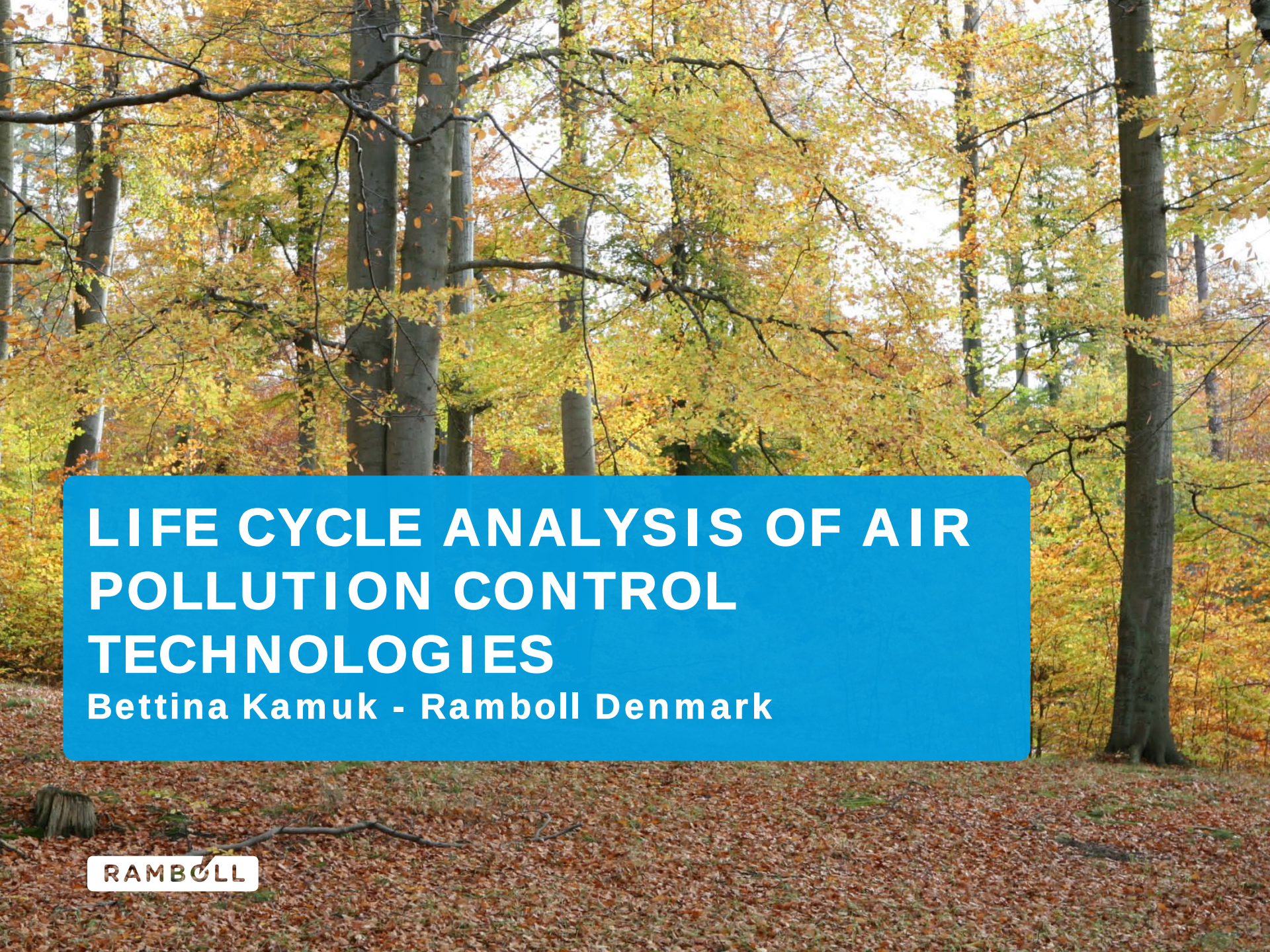


LIFE CYCLE ANALYSIS OF AIR POLLUTION CONTROL TECHNOLOGIES

Bettina Kamuk - Ramboll Denmark

RAMBOLL

RAMBØLL DENMARK

- Established in 1945
- Ramboll consulting group approx. 9,000 employees
- Leading waste-to-energy consultant with >50 specialists within WtE
- Long track record of waste-to-energy plant projects – on-going > 30 WtE projects.
- Independent consulting services

VISIONS FOR THE NEW WTE FACILITY IN COPENHAGEN, DENMARK

- Prominent landmark for the city
- High environmental profile
- High energy profile
- Modern technology
- Flexible for future regulation

=> Ramboll are carrying out a thorough technology study including a detailed LCA for the various APC solutions

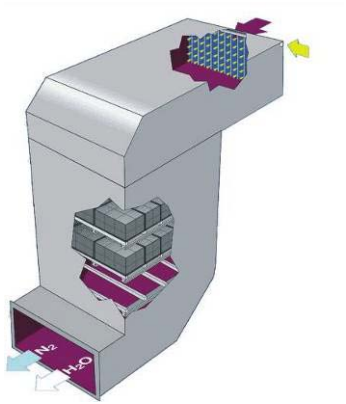
SCENARIOS AFTER SCREENING

- Dry:
  - Electrofilter
  - Reactor (bicarbonate and activated carbon)
  - Baghousefilter
  - Economisers
- Semi-dry:
  - Reactor (hydrated lime and activated carbon)
  - Baghousefilter
  - Economiser
- Semi-wet:
  - Reactor (hydrated lime and activated carbon)
  - Baghousefilter
  - Economiser
  - Quench
  - Wet alkaline scrubber (sodiumhydroxid)
- Wet:
  - Electrofilter
  - Quench
  - Wet acidic scrubber
  - Wet alkaline scrubber (calciumcarbonate)
  - Baghousefilter (activated carbon)
  - Waste water treatment

SCENARIOS FOR DE-NOX

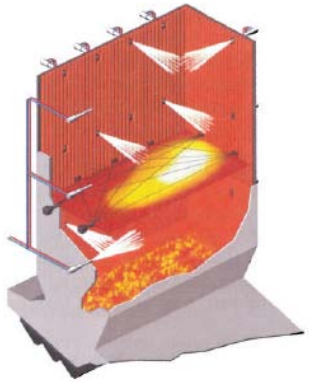
SCR

- Tail-end and front-end solutions are analysed



SNCR

- High-efficient solutions are analysed



EASEWASTE LCA METHODS

- EASEWASTE (*Environmental Assessment of Solid Waste Systems and Technologies)* is developed at the Danish Technical University, and some of Ramboll's employees have been involved in the development of the system
- EASEWASTE models resource use and recovery as well as environmental emissions associated with waste management
- What is evaluated?
    - the process
    - the energyproduction/ consumption
    - the transport of products/residues
    - the treatment of residues

EASEWASTE LCA METHODS – EFFECT CATEGORY

- All impacts are calculated according to "Effect Categories" and the effect is being transferred to a unit comparable within its category using EDIP97 (Environmental Design for Industrial Products)
- *Example: Mercury emitted to air is ending up in fish which is eaten by humans => mercury to air has a humantoxicity to water. The effect is calculated as m3 polluted water*

Impact category	**Unit**
Environmental impacts	
Global	
Global warming	kg CO_2-eq
Ozone depletion	kg CFC-11-eq
Regional and local	
Photochem oz. Form.	kg C_2H_4-eq
Acidification	kg SO_2-eq
Nutrient enrichment	kg NO_3^--eq
-N-equivalents	kg N-eq
-P-equivalents	kg P-eq
Ecotoxicity	
- water acute	m^3 water
- water chronic	m^3 water
- soil chronic	m^3 soil
Human toxicity	
- via air	m^3 air
- via water	m^3 water
- via soil	m^3 soil
Waste	kg

EASEWASTE LCA METHODS – NORM FACTOR

- All effect categories are assessed according to person-equivalents (PE).
- But even though the effects now have same units and can be compared it is not given the various effects have the same importance. EASEWASTE is using the norm-factor given in EDIP97

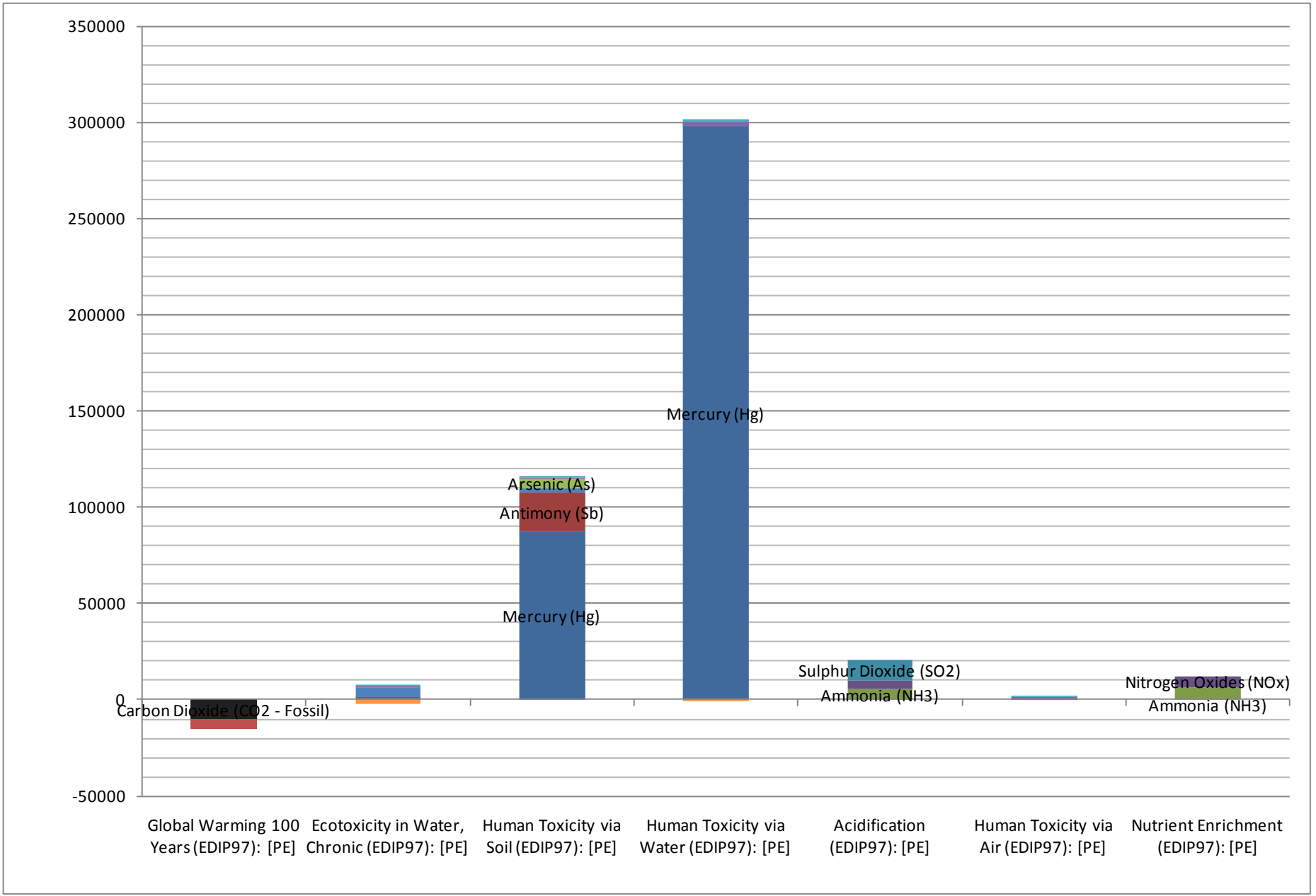
Impact category	Unit	Normalization reference	Reference year
Environmental impacts			
Global			
Global warming	kg CO_2-eq/pers/year	8.70E+03	1994
Ozone depletion	kg CFC-11-eq/pers/ar	0.103	1994
Regional and local			
Photochem oz. Form.	kg C_2H_4-eq/pers/year	25	1994
Acidification	kg SO_2-eq/pers/year	74	1994
Nutrient enrichment	kg NO_3^--eq/pers/year	119	1994
-N-equivalents	kg N-eq/pers/year	24	1994
-P-equivalents	kg P-eq/pers/year	0.4	1994
Ecotoxicity			
- water acute	m^3 water/pers/year	2.91E+04	1994
- water chronic	m^3 water/pers/year	3.52E+05	1994
- soil chronic	m^3 soil/pers/year	9.64E+05	1994
Human toxicity			
- via air	m^3 air/pers/year	3.06E+09	1994
- via water	m^3 water/pers/year	5.22E+04	1994
- via soil	m^3 soil/pers/year	1.27E+02	1994

EASEWASTE LCA METHODS–WEIGHING FACTOR

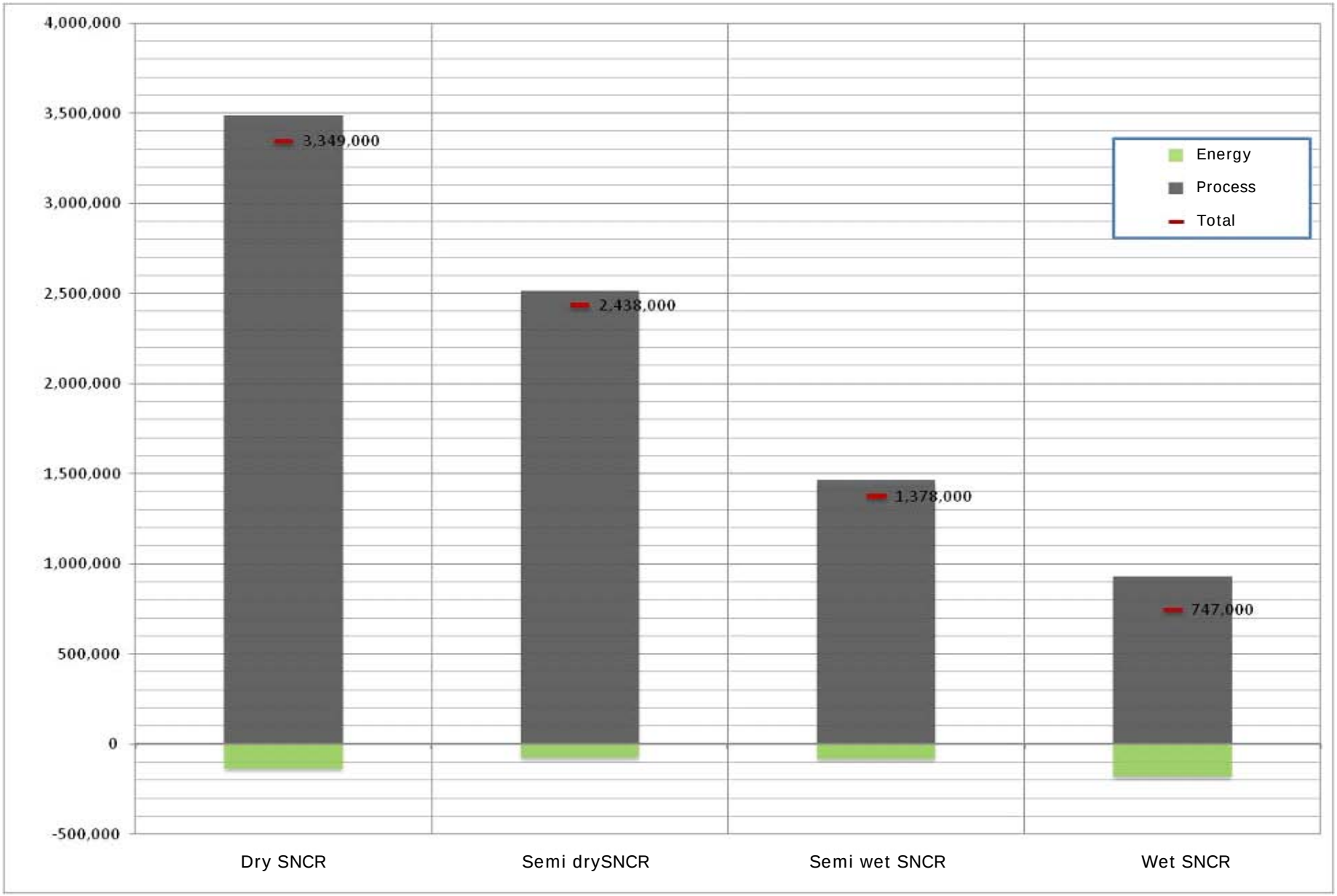
- Weighing of the impacts should consider:
  - how far from threshold limit?
  - will the impact be irreversible?
  - which consequences do occur?
- In order to do an objective evaluation a politically accepted weighing factor are used according to EDIP97

Impact category	Weighting factor	Reference year	Reference region
Environmental impacts			
Global			
Global warming	1.1	2004	World
Ozone depletion	63	2004	World
Regional and local			
Photochem oz. Form.	1.3	2004	EU-15
Acidification	1.3	2004	EU-15
Nutrient enrichment	1.2	2004	EU-15
-N-equivalents	1.4	2004	EU-15
-P-equivalents	1	2004	EU-15
Ecotoxicity			
- water acute	1.1	2004	EU-15
- water chronic	1.2	2004	EU-15
- soil chronic	1	2004	EU-15
Human toxicity			
- via air	1.1	2004	EU-15
- via water	1.3	2004	EU-15
- via soil	1.2	2004	EU-15
Waste			
-bulk Waste	1.1	2000	Denmark
-hazadous waste	1.1	2000	Denmark
-slag and ashes	1.1	2000	Denmark
-nuclear waste	1.1	2000	Sweden

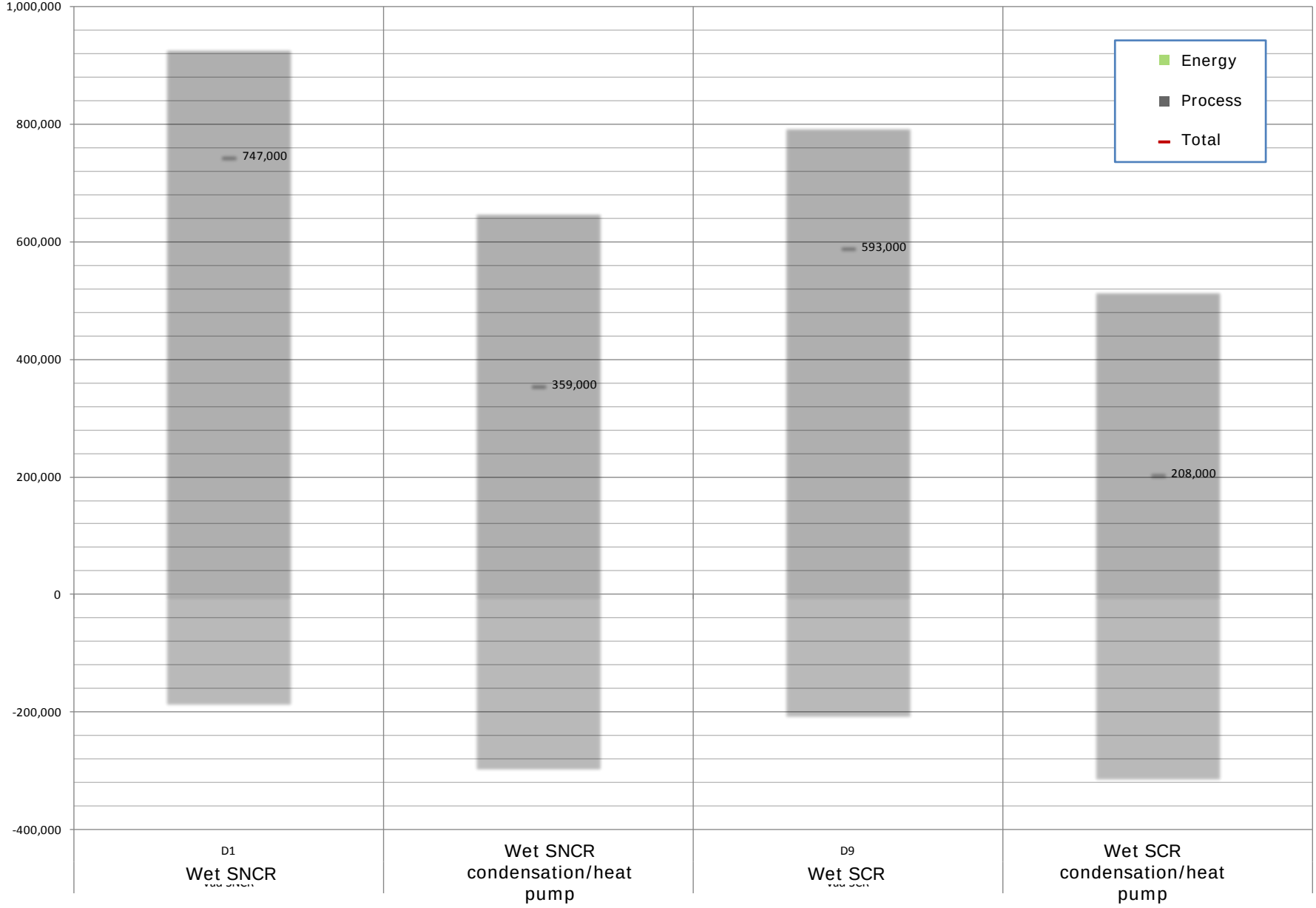
LCA RESULTS – HIGHEST IMPORTANCE?



LIFE CYCLE ANALYSIS OF SCENARIOS?



LCA SNCR OR SCR – WITH CONDENSATION?



EASEWASTE LCA CONCLUSION

- Mercury (Hg) emission is the most important component to control as it has the highest LCA impact
- The energy production should be optimised as a high energy recovery will compensate the negative impact
- Wet APC system has lower impact than dry, semi-dry and semi-wet solutions – 2 to 5 times lower
- SCR better than SNCR
- Flue gas condensation improves the impacts significantly (if the heat can be used and because it reduces Hg-emission)

IS THE LCA IN LINE WITH THE FINANCIAL ANALYSIS?

APC concept Financial analysis (excl. tax)	Dry SNCR (mill. $)	Semi-dry SNCR (mill. $)	Semi-wet SNCR (mill. $)	Wet SNCR (mill. $)
Investment (extra investment compared to semidry)	3,5	Reference	14,0	34
Operational Costs (20 years) (extra investment compared to semidry)	-7,0	Reference	-7,0	-57
Present Value (extra investment compared to semidry)	**-3,5**	**0**	**7,0**	**-23**

IS THE LCA IN LINE WITH THE FINANCIAL ANALYSIS?

DeNOx technology Financial analysis (excl. tax but incl. NOx-fee at 2.3 $/lb NOx)	Wet SNCR (mill. $)	Wet SCR (mill. $)
Investment (extra investment compared to SNCR)	Reference	14,2
Operational Costs (20 years) (extra investment compared to SNCR)	Reference	-10,7
Present Value (extra investment compared to SNCR)	**0**	**3,5**

IS THE LCA IN LINE WITH THE FINANCIAL ANALYSIS?

Condensation incl. heatpump **Financial analysis (excl. tax)**	**Wet SCR no condens.** **(mill. $)**	**Wet SCR with condens.** **(mill. $)**
Investment (extra investment compared to no condensation)	Reference	32,2
Operational Costs (20 years) (extra investment compared to no condensation)	Reference	-42,9
Present Value (extra investment compared to no condensation)	**0**	**-10,7**

THANK YOU FOR YOUR ATTENTION!

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