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Eco-efficiency analysis of plasma based environmental technologies

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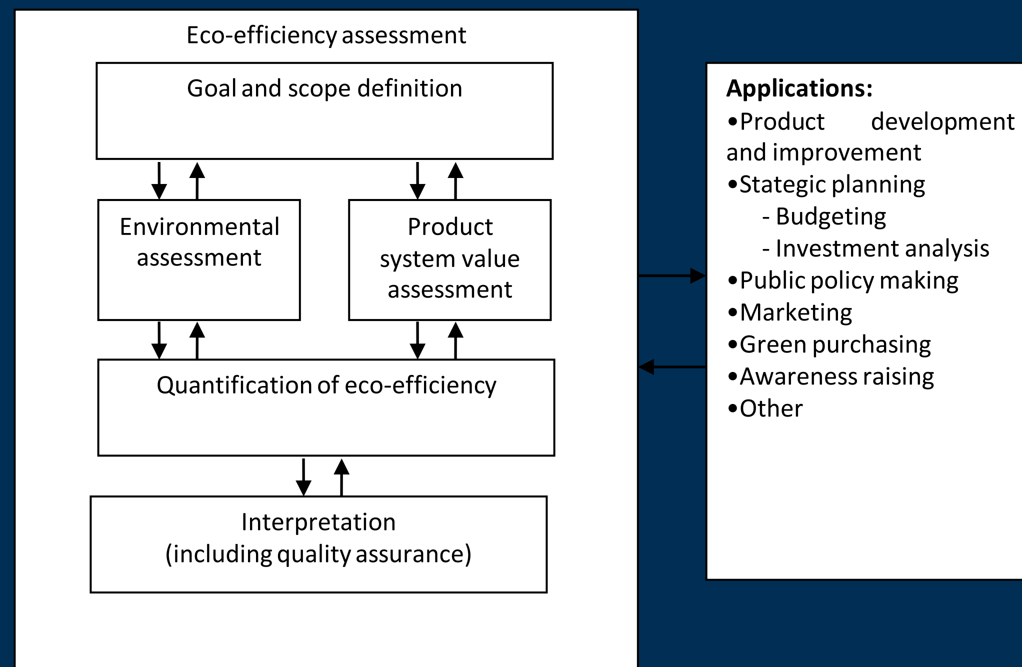
Applications of plasma for the environmental technologies

- Characterized as a very reactive media, thus capable in destroying various forms of hazardous substances
- Has been demonstrated for variety of applications
  - Energy sector flue gas treatment
  - Ventilation exhaust/intake/indoor air treatment
  - Drinking water decontamination
  - Wastewater treatment
  - Environmental spill management
  - Thermal disposal of solid waste
  - Decontamination of polluted soils

  Etc.

Eco-efficiency

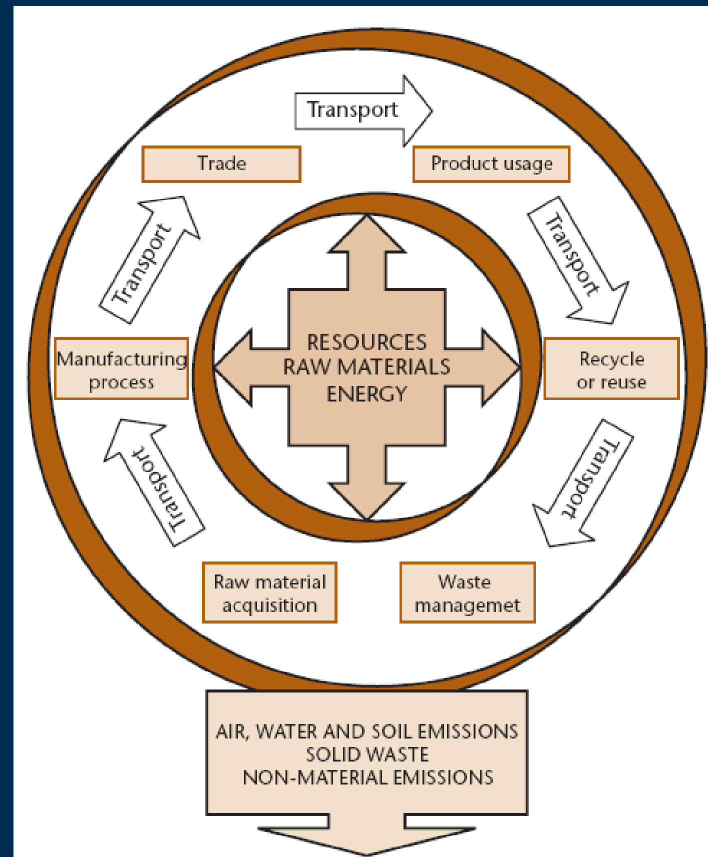
- Eco-efficiency assessment is a quantitative management tool which enables the consideration of life cycle environmental impacts of a product system alongside its product system value to a stakeholder.



Eco-efficiency

It employs life cycle analysis technique, which considers the entire life cycle of a product or technology:

- from raw material extraction and acquisition,
- through energy and material production and manufacturing,
- to use and end of life treatment and final disposal



Product Design and Life Cycle Assessment, 2006

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The methodology of the LCA

- The methodology is well standardized (ISO 14040:2006, forthcoming standard for eco-efficiency assessment ISO/DIS 14045)
- Gabi 4 (PE international) software equipped with Eco-invent database was utilized for modeling of the LCA.
- Impact category system CML2001 was employed for the Life cycle impact assessment (LCIA).

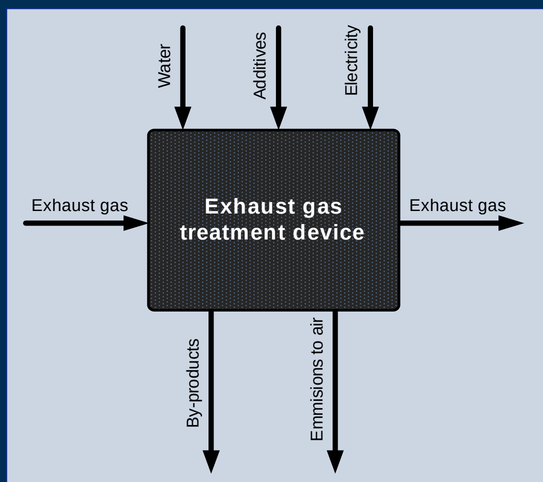
The methodology of the LCA (cont'd)

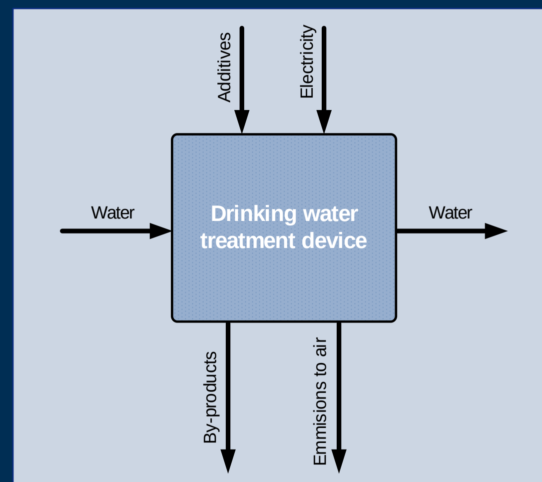
The analysis was carried out by comparing several standardized units, involving plasma and non-plasma ("conventional" end-of-pipe) technologies

SOx/NOx treatment	VOCs treatment	water decontamination
Electron Beam Flue Gas Treatment	PlasmaNorm (DBD based)	Electrohydraulic discharge
vs.	vs.	vs.
Wet Flue Gas Desulfurization+ Selective Catalytic Reduction	Zeolite regenerative sorption and Biofiltration	UV disinfection and Ozone disinfection by PEM

The methodology of the LCA (cont'd)

- Process boundary was established, based only on processes





- The functional unit was set as 1000 Nm^3 of treated flue gases, or 1 m^3 of treated water.

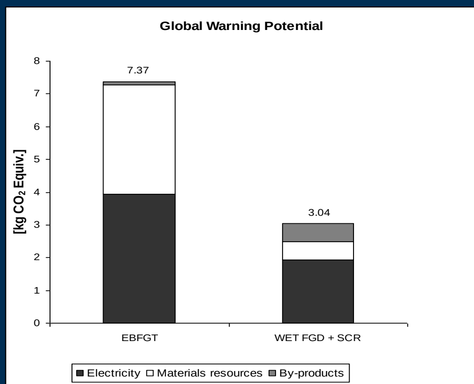
The methodology of the LCA (cont'd)

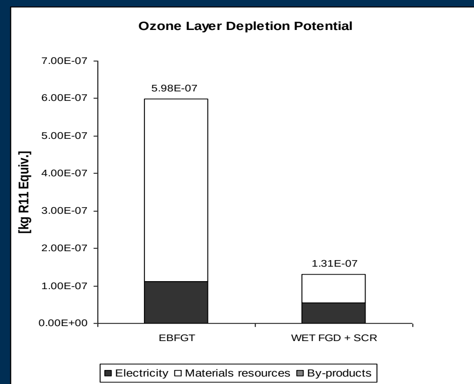
- Inventory analysis

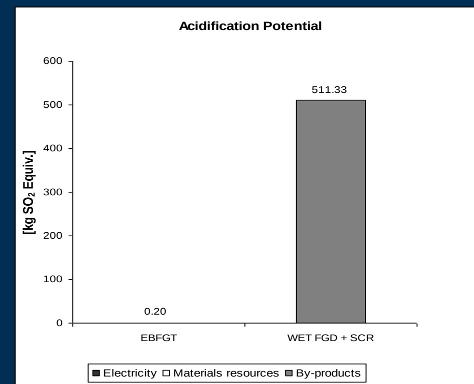
Example of VOCs

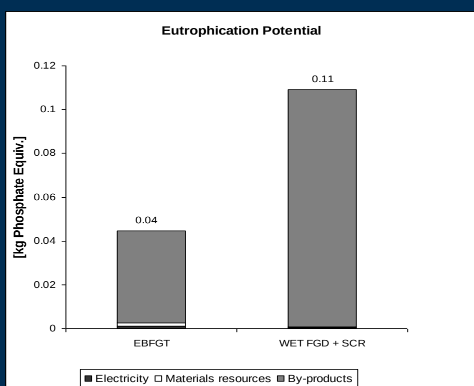
Parameter		Method		
		DBD	Regenerative sorption (zeolite rotor)	Biofilter
Flue gas flow	Nm3/h	600	50000	150000
Inlet concentrations				
Aliphatic hydrocarbons	mg/Nm3	240	300	150
Outlet concentrations				
Aliphatic hydrocarbons	mg/Nm3	0.24	9	10
Additive				
Natural gas	m3/d	-	408	-
Compressed air	m3/d	-	60	-
Removal efficiency	%	99.9	97	93
Electrical power consumption	kWh	0.15	65	150
Hydrosorb material	kg	0.21	-	-
AC material	kg	0.31	-	-
Zeolite	kg	-	18600	-
Water	m3/d	-	-	36
Biofilter (Leaf compost, Wood chips)	m3	-	-	1500
By-product				
Hydrosorb material	kg	>0.21	-	-
AC material	kg	>0.31	-	-
CO2	kg	0.102	10.5	15
Wastewater	m3	-	-	1.44
Zeolite	kg	-	18600	-
Biofilter (Leaf compost, Wood chips)	m3	-	-	1500

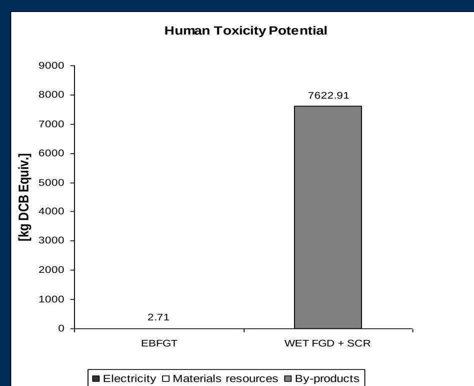
Results – SOx/NOx treatment

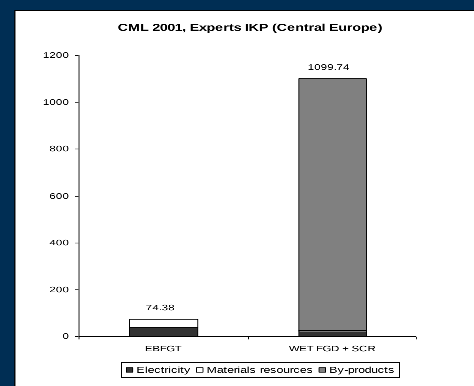




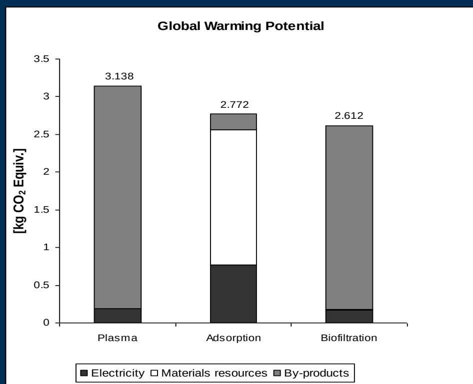


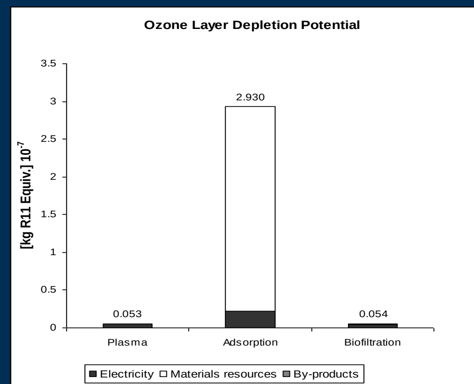


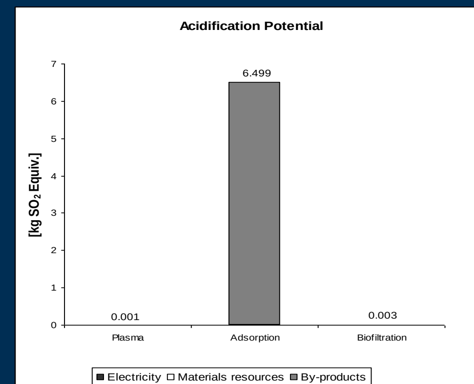


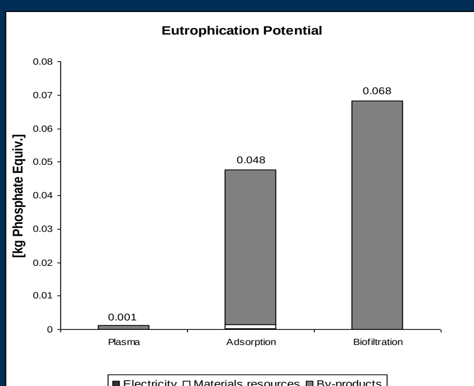


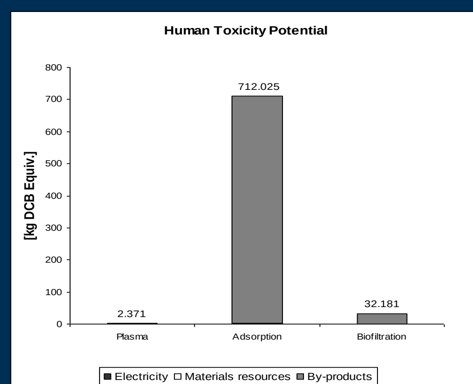
Results – VOC treatment

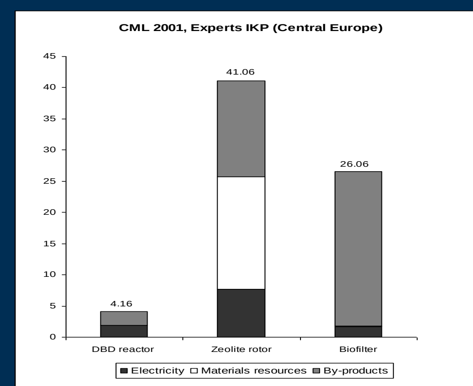




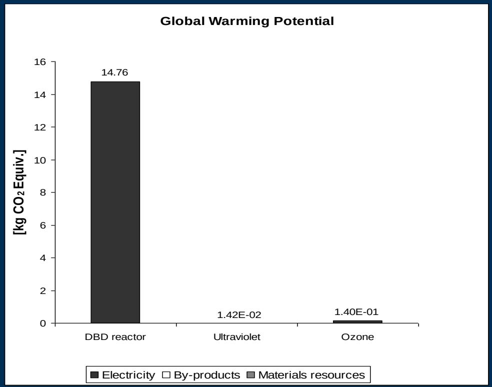


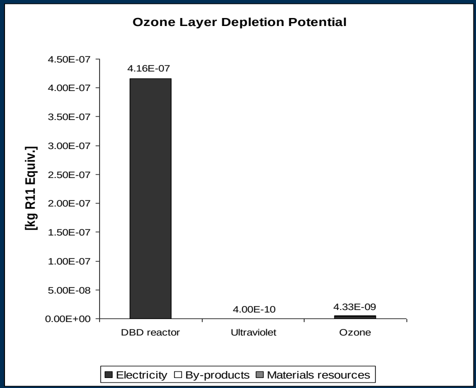


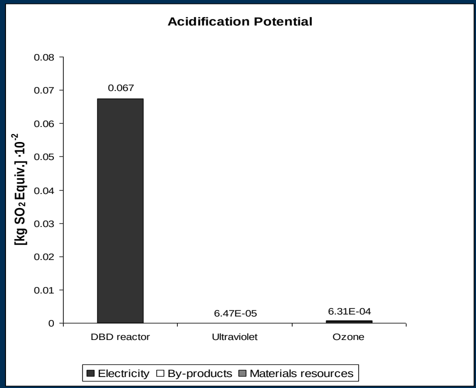


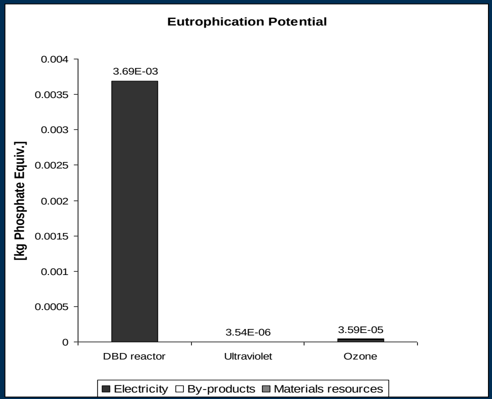


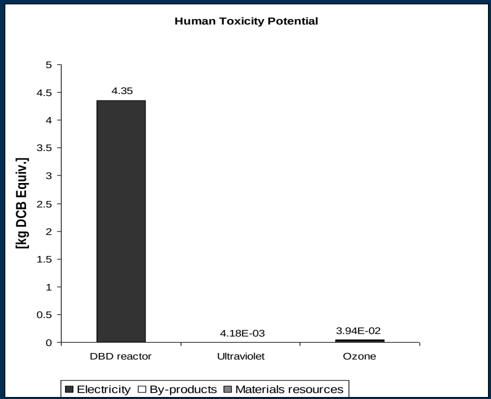
Results – Water Treatment

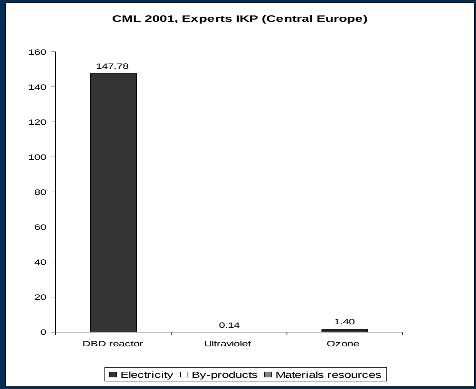












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Conclusions

- The eco-efficiency analysis based on life cycle analysis proved to be a suitable tool for the assessment of environmental performance of plasma and non-plasma end-of pipe technologies, although certain limitations exist.
- In case of SOx/NOx treatment, EBFGT performed better compared to WFGD+SCR with respect to acification, eutrophication, and human toxicity potential due to the possible utilization of by-products; on the other hand, due to higher energy consumption, it was worse with respect to global warming potential and ozone layer depletion.

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Conclusions (cont'd)

- In case of VOC treatment, DBD-based plasma unit successfully competed with zeolite adsorption and biofiltration unit. The energy consumption was not a major contributor, but the management of remaining waste caused the highest impact to the environment.
- In case of simple water treatment systems, energy consumption played the main role in environmental performance. With the highest energy consumption between tested alternatives, the electro hydraulic discharge unit was the least favorable option.