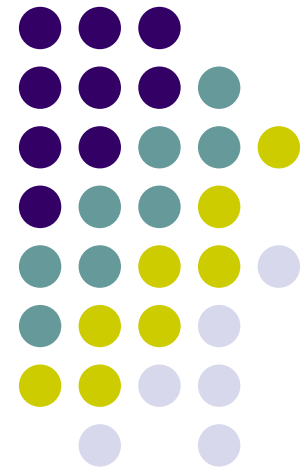


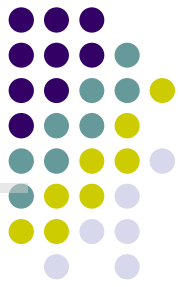
# Life cycle assessment (LCA) of waste management systems



Development and testing of an operational model  
- EASEWASTE

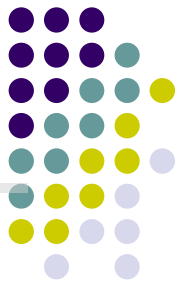


# Life cycle thinking in WMS



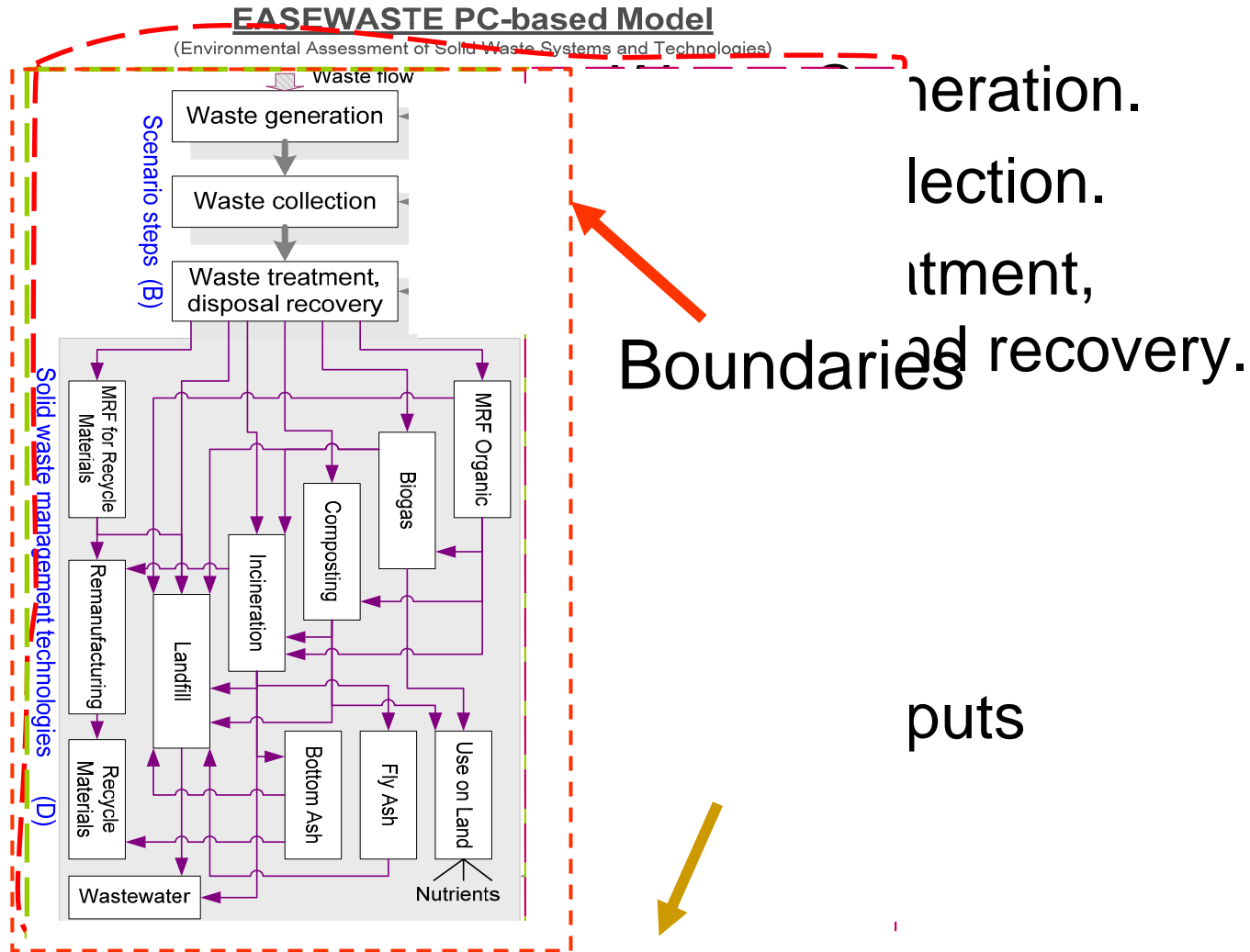
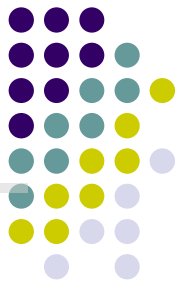
- LCA is for environmental assessment of systems.
- LCA identifies the most environmentally significant.
  - processes in the waste management system.
  - burdens from the waste management system.
- LCA qualifies and quantifies actual improvements (local optimization or global improvement?)
- Waste hierarchy may not be valid in all situations.

# What is the EASEWASTE model?

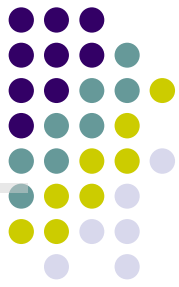


- PC-Based LCA model for decision support on waste management systems
- Ecological (environmental impact and resource consumption) and economical profile (costs and externalities).
- Flexible, transparent, and user-friendly.
- Large database (external and internal processes).
- Covering residential, bulky and garden waste.
- Available in two versions (EASEWASTE2004 and EASEWASTE 2006)

# Model structure

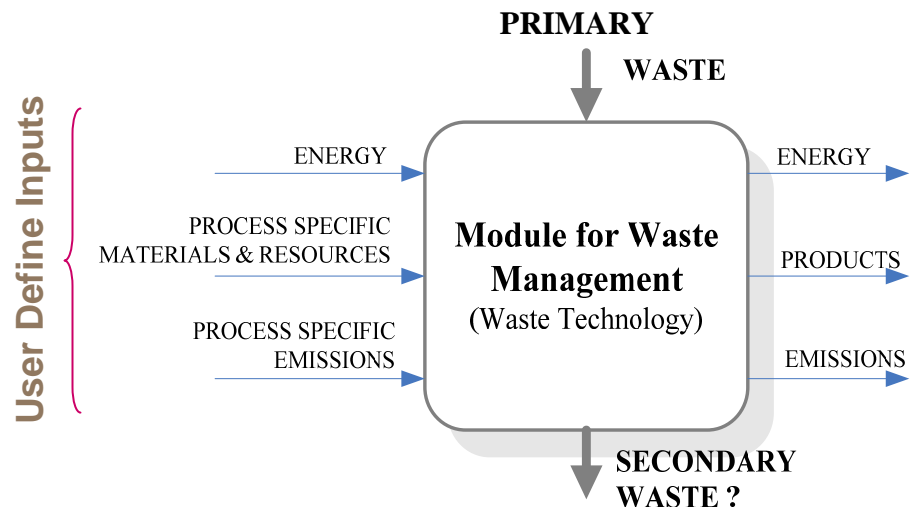


# Modules in EASEWASTE

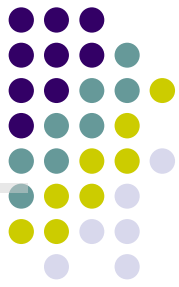


One module for each waste treatment method:

- MRF – Organics and non-organics
- Incineration
- Bio-technologies – (Anaerobic and composting).
- Remanufacturing.
- Material utilization.
- Landfilling.
- Use-on-land.
- Bottom ash.
- Fly ash.
- Reuse-in-construction.



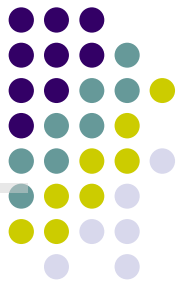
# EASEWASTE



- EASEWASTE Model demonstration

View Model 2006

# Sensitivity analysis (ratio)



Category Name	Water from waterworks, Danish	Danish electricity, based on coal, Studstrup powerplant, Terminated (kWh)	Danish district heating, coal Studstrup powerplant, Terminated	Diesel oil combusted in truck, EU2, Terminated (l)	Plastic bags for optic sorting (low density)
Stratospheric ozone depletion (EDIP97): [kg CFC11-Equiv.]	0	0	0	0	
Global warming 100 years (EDIP97): [kg CO2-Equiv.]	2.333E-7	0.3405	0.05061	0.003441	
Acidification (EDIP97): [kg SO2-Equiv.]	0	0.8482	0.1261	0.02569	
Human toxicity air (EDIP97): [m3 air/kg]	0	0.8462	0.1279	0.0259	
Ecotoxicity water chronic (EDIP97): [m3 water/kg]	0	0.7279	0.1227	0.1494	
Ecotoxicity soil (EDIP97): [m3 soil/kg]	0	0.7329	0.2286	0.03853	
Nutrient enrichment (EDIP97): [kg NO3-Equiv.]	0	0.8464	0.1259	0.02776	
Photochemical ozone formation, high NOx (EDIP97): [k...	3.498E-6	0.6416	0.09542	0.01235	

Module Name	Total Amount	Stratospheric ozone depletion (EDIP97): [kg CFC11-Equiv.]	Global warming 100 years (EDIP97): [kg CO2-Equiv.]	Acidification (EDIP97): [kg SO2-Equiv.]	Human toxicity air (EDIP97): [m3 air/kg]
Water from waterworks, Danish	3.731E-6	0	2.333E-7	0	
Danish electricity, based on coal, Studstrup power...	4.984	0	0.3405	0.8482	0.84
Danish district heating, coal Studstrup powerplant,...	0.8772	0	0.05061	0.1261	0.12
Diesel oil combusted in truck, EU2, Terminated (l)	0.2831	0	0.003441	0.02569	0.02
Plastic bags for optic sorting (low density)	0.8561	0	0.6055	0	

Normalisation [Sensitivity Ratio]

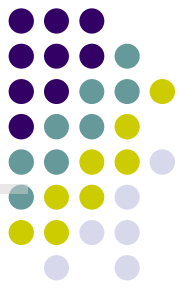


- Stratospheric ozone depletion (EDIP97): [kg CFC11-Equiv.]
- Global warming 100 years (EDIP97): [kg CO2-Equiv.]
- Acidification (EDIP97): [kg SO2-Equiv.]
- Human toxicity air (EDIP97): [m3 air/kg]
- Ecotoxicity water chronic (EDIP97): [m3 water/kg]
- Ecotoxicity soil (EDIP97): [m3 soil/kg]
- Nutrient enrichment (EDIP97): [kg NO3-Equiv.]
- Photochemical ozone formation, high NOx (EDIP97): [kg Ethene-Equiv.]

Screen whole system and identify most sensitive processes

$$SR = \frac{\Delta Output\_Variable\_i}{Output\_Variable\_i} \div \frac{\Delta Input\_Variable\_m}{Input\_Variable\_m}$$

# Sensitivity analysis (Single parameter)

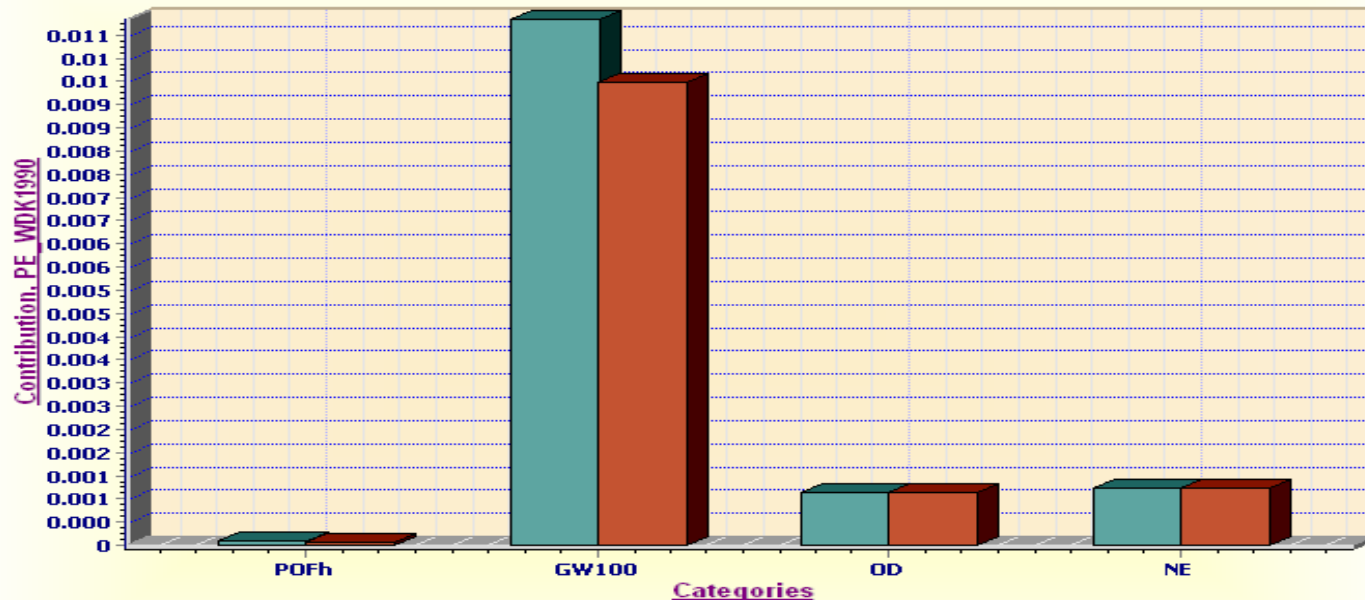


## Sensitivity Analysis Optimisations

No.	Name	Type	Total Amount	Unit	Analysis [%]
1	Water from waterworks, Danish	Process/Material	100	kg	% 0
2	Danish electricity, based on coal, Studstrup powerplant, Terminated (kWh)	Process/Material	39	kWh	% 0
3	Danish district heating, coal Studstrup powerplant, Terminated	Process/Material	52.2	MJ	% 0
4	Diesel oil combusted in truck, EU2, Terminated (l)	Process/Material	0.1	l	% 0
5	Plastic bags for optic sorting (low density)	Process/Material	12.3	kg	% 20

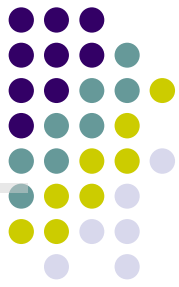
Perform scenario analysis for relevant processes

Normalisation Sensitivity Analysis [20% reduction in plastic bags for optic sorting]



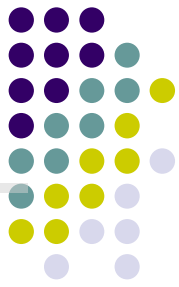
- LCA Results: [Aarhus Optic Sorting, Organic Waste]
- LCA Results: [Aarhus Optic Sorting, Organic Waste] [Analysis Results]

# Accomplishments of the model

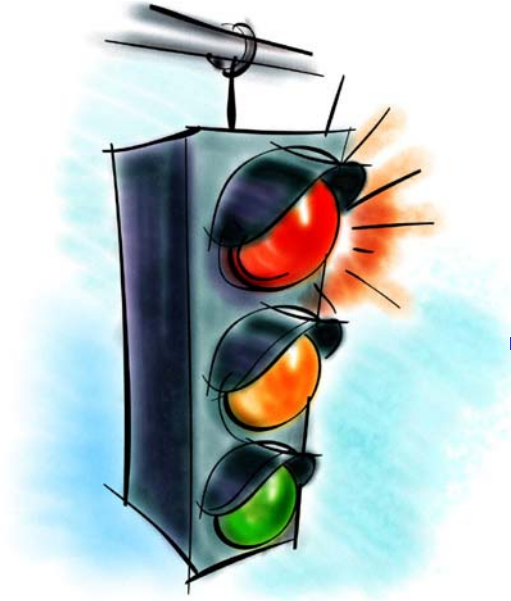
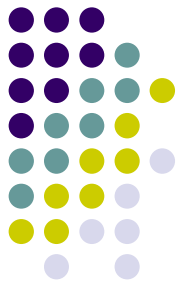


- User friendly interface.
- Flexible in terms of
  - waste input and composition,
  - definition of waste technologies,
  - analysis and presentation of results.
- Database with default process data and LCIA and economic factors.
- Single process evaluation.
- Flexibility in modeling.

# Limitations of the model



- Database capacity restrictions causes limitations in:
  - Number of material fractions and chemical substances for each material fraction,
  - Number of sorting efficiencies and fractions.
- Limited number of waste types supported (household waste, garden waste and bulky waste).
- External unit processes are described by terminated data at one level in order to avoid eternal loops in the program leading to instability.



# THANK YOU FOR LISTENING!

# Comparison to existing tools



	EASEWASTE	ORWARE	ISWM DST	IWM2	Wisard
Developed by:	DK	Sweden	US EPA	UK	UK
Purpose	Decision Support, Res. tool	Decision Support, Res. tool	Opti. Model, Res. tool	Decision Support	Decision Support, Res. Tool?
Waste streams	MSW	MSW+Ind.	MSW	MSW	MSW
Material fractions	65	12	35	8	41
Waste composition	Yes	Yes	No	No	Yes
Waste tech.	Unlimited	1	1	1	1
LCIA calculations	Inven+Chr +Nor+Wg.	Inven.+ Chr	Inven.	Inven.	Inven.+ Chr, Nor.
S. Pro. evaluation	Yes	No	No	No	No
External processes	Yes	No	No	No	Yes
Sensitivity analysis	Yes	No	No	No	No
User Friendly	+++	+	+	+++	++