VENEZIA RICERCHE
Ricerca applicata e trasferimento tecnologico

LIFE CYCLE ASSESSMENT OF NANOPARTICLES USE IN MEMBRANE

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SEVENTH FRAMEWORK PROGRAMME

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Content of presentation

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- Conclusions
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Introduction

According to the EU report “Membrane technologies for water applications - Highlights from a selection of European research projects” (EC, 2010; EUR 24552 EN), nanotechnologies (NTs) may play an important role in water treatment through, e.g.

modification of membrane characteristics with engineered nanoparticles (ENPs)

the use of nanomaterials (NMS) to adsorb specific contaminants or to catalyse degradation reactions

Introduction

However, to ensure a safe and sustainable use of NTs for water treatment, the potential benefits should be weighted against any potential effects on the environment and human health, especially in an early stage of NMs application, such as:

•evidence for toxic effect of ENPs is increasing;

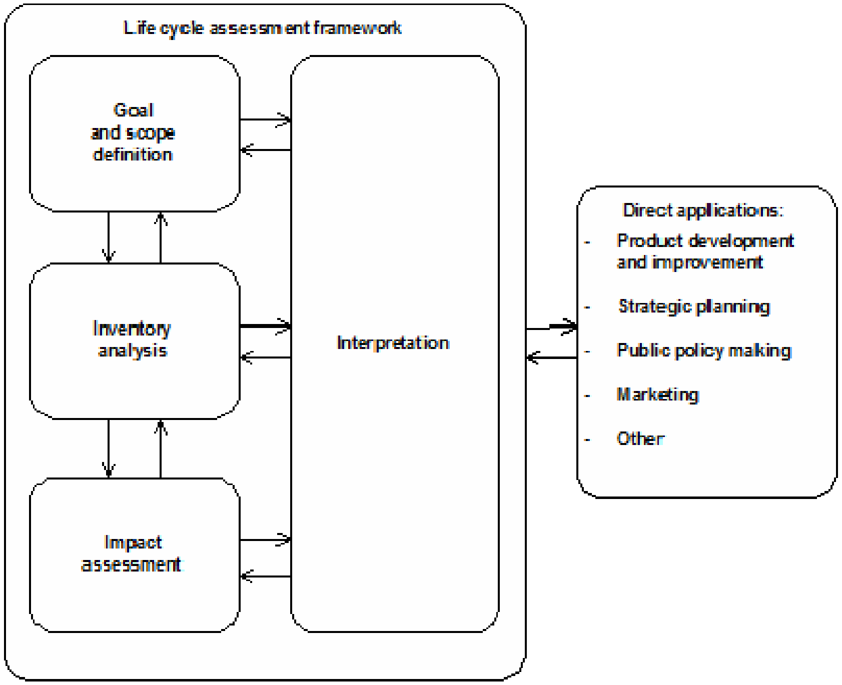
•uncontrolled release of ENPs to the environment from nano-based products has been recently demonstrated in textile (Geranio et al., 2009) and façade coating (Kaegi et al., 2010; 2008);

•environmental behaviour of released ENPs isn't well investigated!

Introduction

One approach that may be applied to analyze the possible impacts of nano-based products is **Life Cycle Assessment (LCA)**.

LCA can be used to evaluate how a product (or service) - from the extraction of raw materials through end-of-life – affects ecosystems and human health by compiling an inventory of relevant inputs and outputs, evaluating the potential environmental impacts associated with those inputs and outputs.

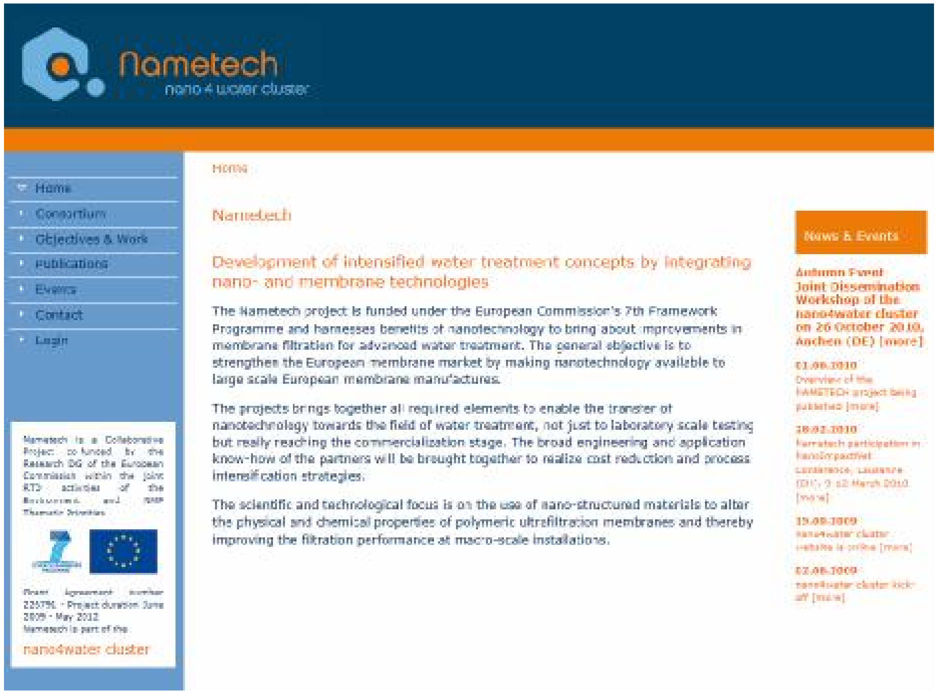


LCA framework (ISO 14040; 2006)

Introduction

In the EU project ***NAMETECH - Development of intensified water treatment concepts by integrating nano- and membrane technologies***, a LCA methodology is applied to the use of titanium dioxide (TiO_2) and silver (Ag) ENPs in polyethersulfone (PES) membranes.

Two processes: electrostatic deposition (ED) and mixed matrix membrane (MMM).



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LCA case study

Goal of the study

- A cradle to gate environmental assessment of TiO_2 ENPs deposition on PES membrane surface
- Analysis of main contributes to membrane manufacturing

Scope of the study

- PES flat sheet membranes for water treatment

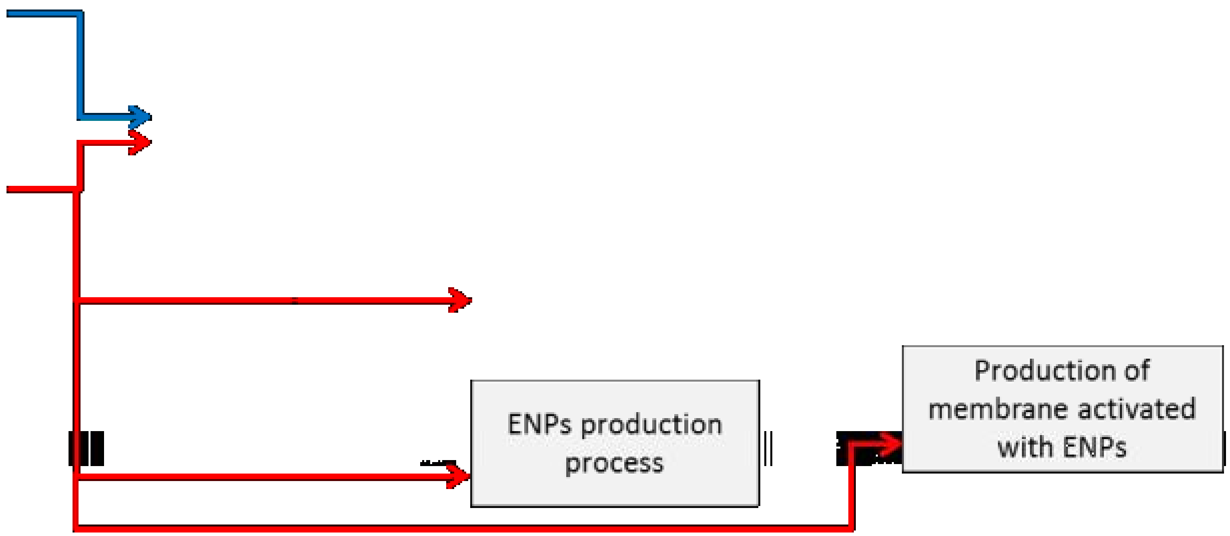
Functional unit

- The capability of treating 1 m^3 of feed per hour per m^2 of PES membrane activated with TiO_2 ENPs

LCA case study

System boundary

•A cradle to gate, i.e. a partial product life cycle, from resource extraction to the factory gate. The use phase and disposal phase of the product are not included.



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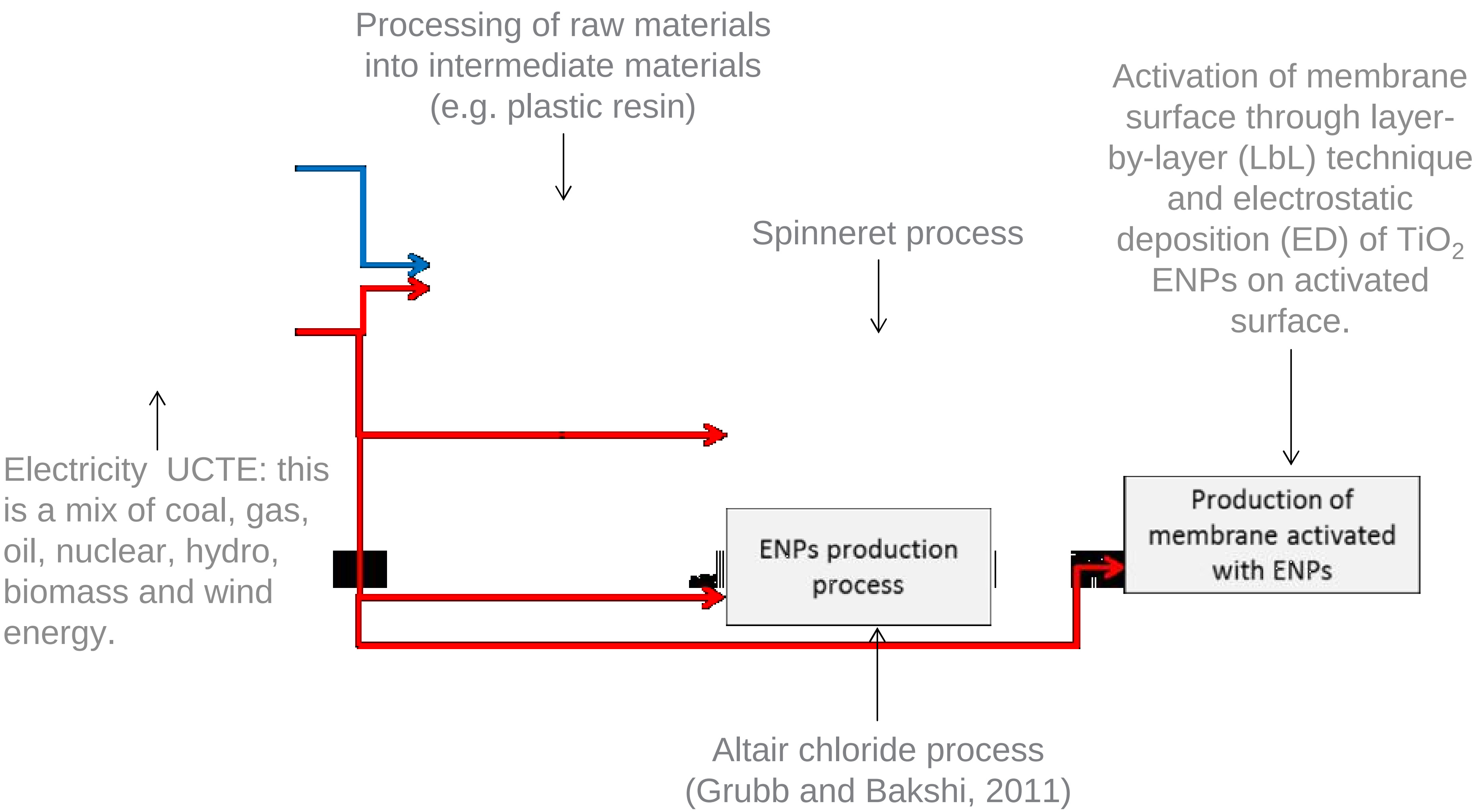
System boundary



System boundary

•Details of processes investigated

LCA case study

Data source

•Primary data from NAMETECH partner with regard to membrane manufacturing, LbL and ED processes;

•Secondary data from

- Literature, e.g. inventory data of TiO_2 ENPs production by Altair hydrochloride process (Grubb and Bakshi; 2011)
- Life Cycle Inventory database included in LCA tool (SimaPro 7.1), e.g. Ecoinvent database
- PE International for PES production (data set of polymerization of 4,4'-Dichlorodiphenylsulfone monomers)

LCA case study

Process	Data source	Data set
Acquisition of raw materials	[redacted]	[redacted]
	Plastic Europe	PVC resin
	[redacted]	[redacted]
	Grubb and Bakshi, 2011	TiO_2 ENPs production
[redacted]	[redacted]	[redacted]
Energetic processes	Ecoinvent	Electricity, production mix UCTE
	[redacted]	[redacted]
	ETH-ESU 96	On site steam average E
[redacted]	[redacted]	[redacted]

LCA case study

Impact categories

The impact assessment of manufacturing of PES membrane activated with TiO_2 ENPs was performed by applying the

1. CML methods (Guinée et al., 2001), on the basis of the following midpoint indicators:

   – **abiotic depletion factor (ADF),** i.e. depletion of minerals and fossil fuels, impact category expressed as kg Sb eq/kg extraction;
   – **global warming potential (GWP),** expressed as kg CO_2/kg emission (GWP IPCC 2001, 100 yr);
   – **acidification potential (AP)** related to the acidifying substance, expressed as SO_2 eq/kg emission;
   – **eutrophication potential (EP)**, expressed as kg PO_4^{3-} eq/kg emission;
   – **human toxicity potential (HTP),** and **fresh-water, marine aquatic and terrestrial eco-toxicity (FAETP, MAETP** and **TETP)** as kg 1,4-dichlorobenzene eq/kg emission;
   – **ozone layer depletion potential (ODP)**, expressed as kg CFC-11 eq/kg emissions
   – **photochemical oxidation (POCP)**, i.e. the formation of reactive substances, expressed as kg ethylene eq/kg emission

LCA case study

Impact categories

2.Eco-indicator ‘99 method (Goedkoop and Spriensma, 2000), on the basis of the following endpoint indicators (damage category):

- **Damage to Human Health** expressed in Disability Adjusted Life Years (DALY)
- **Damage to Ecosystem Quality** expressed in Potentially Disappeared Fraction (PDF) multiplied by the area size and the time period (PDF*m^2*yr).
- **Damage to Resources** expressed as surplus energy (J) for the future mining of resources (MJ surplus)

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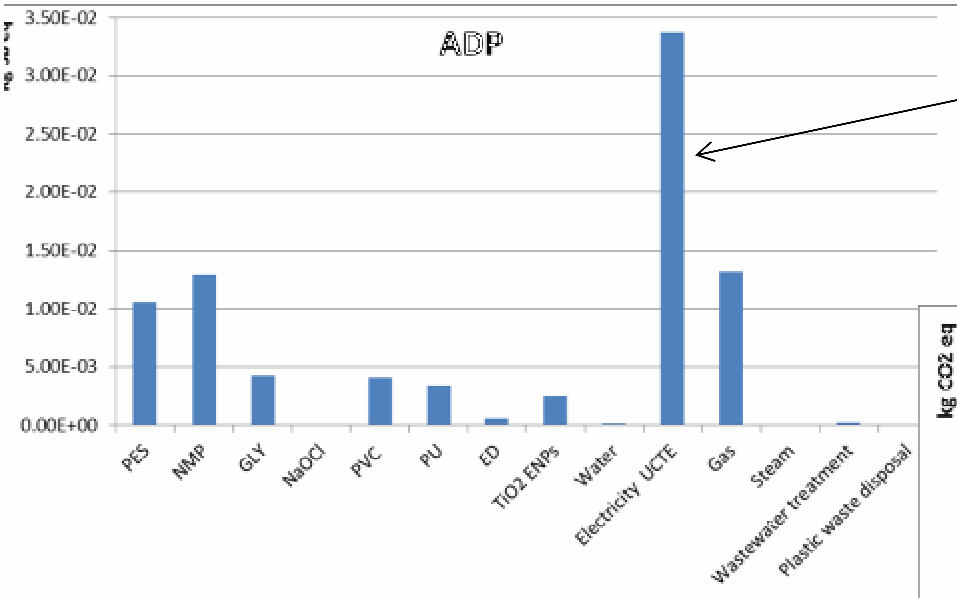
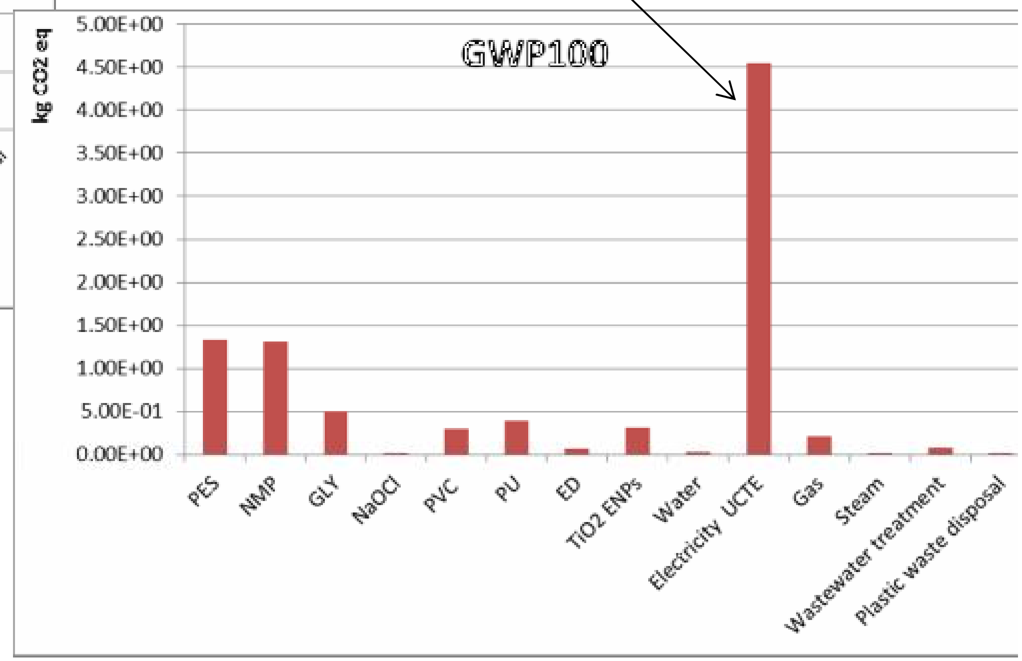
Results

Resource depletion (ADP) and global warming (GWP)



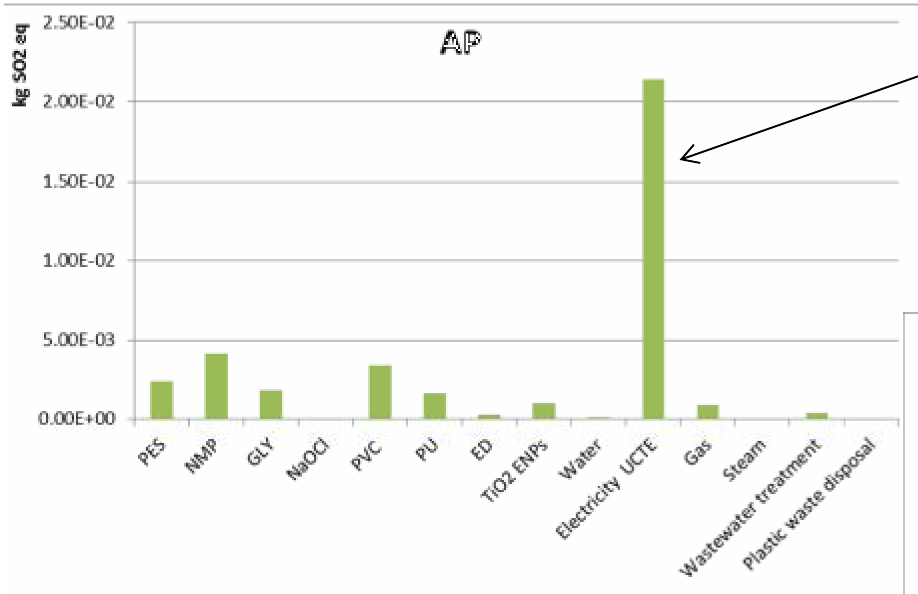
Extraction and use of fossil fuel for electricity production. Electricity is mainly used for membrane manufacturing



Electricity UCTE - Union for the Coordination of the Transmission of Electricity: this is a mix of coal, gas, oil, nuclear, hydro, biomass and wind energy.

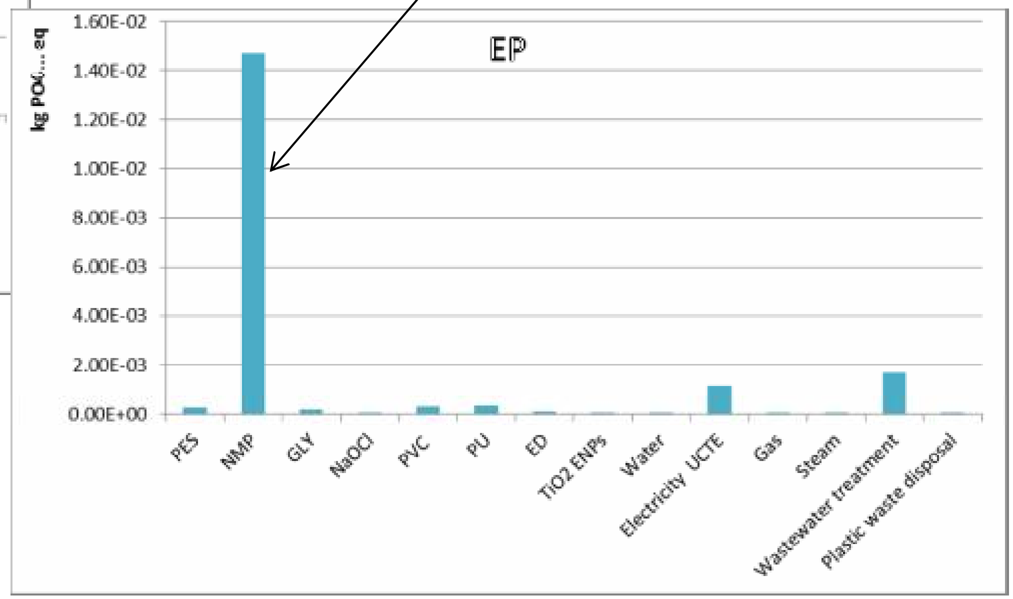
Results:

Acidification (AP) and eutrophication (EP)



SO_2 emissions to air from the electricity required for membrane manufacturing

Ammonium emissions to water from the production process



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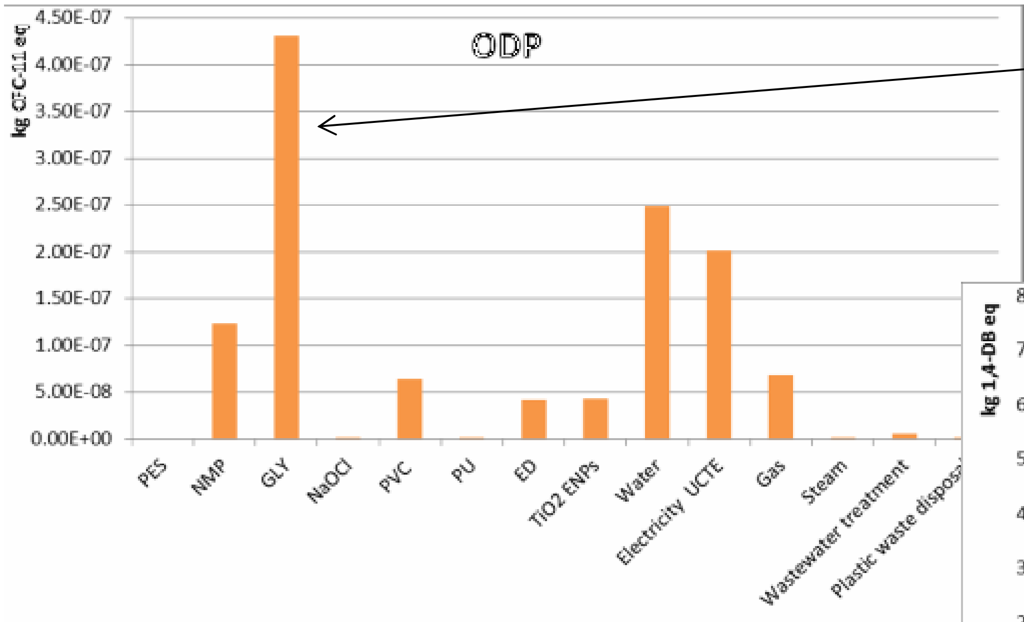
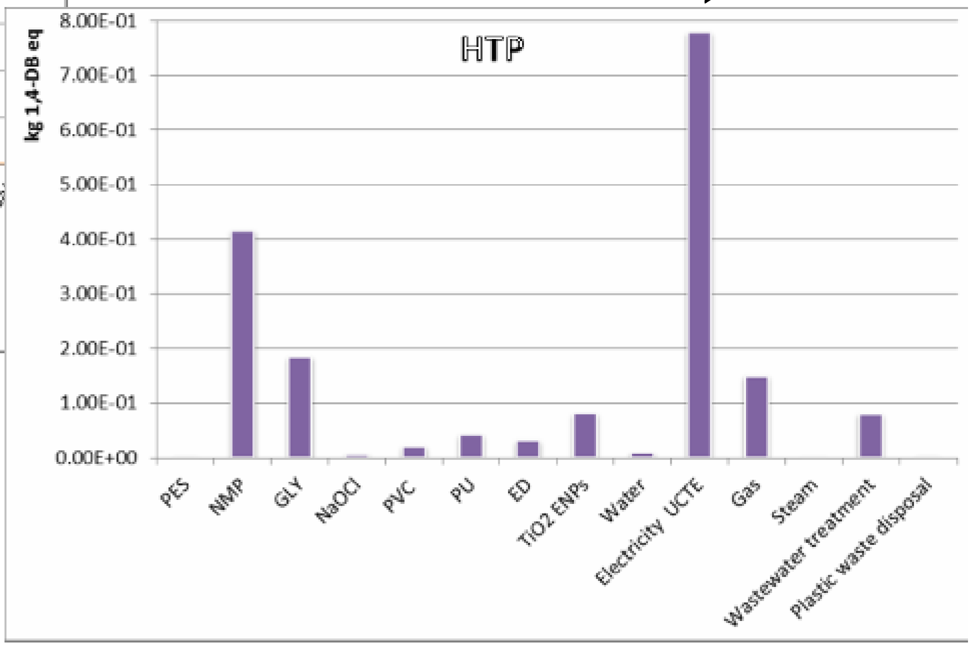
Results

Ozone depletion (ODP) and human toxicity (HTP)



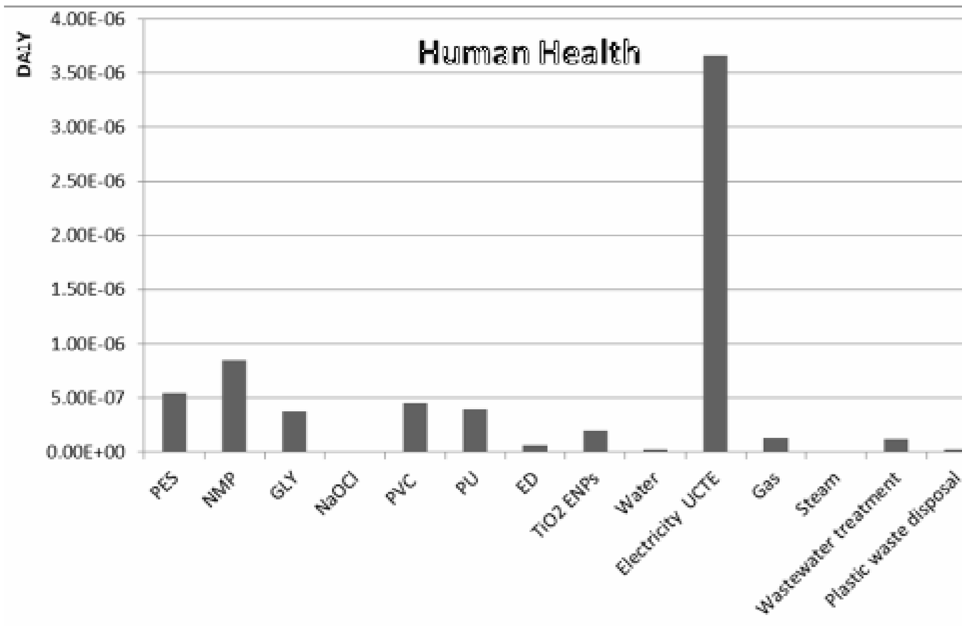
CFC emissions to air from the production process

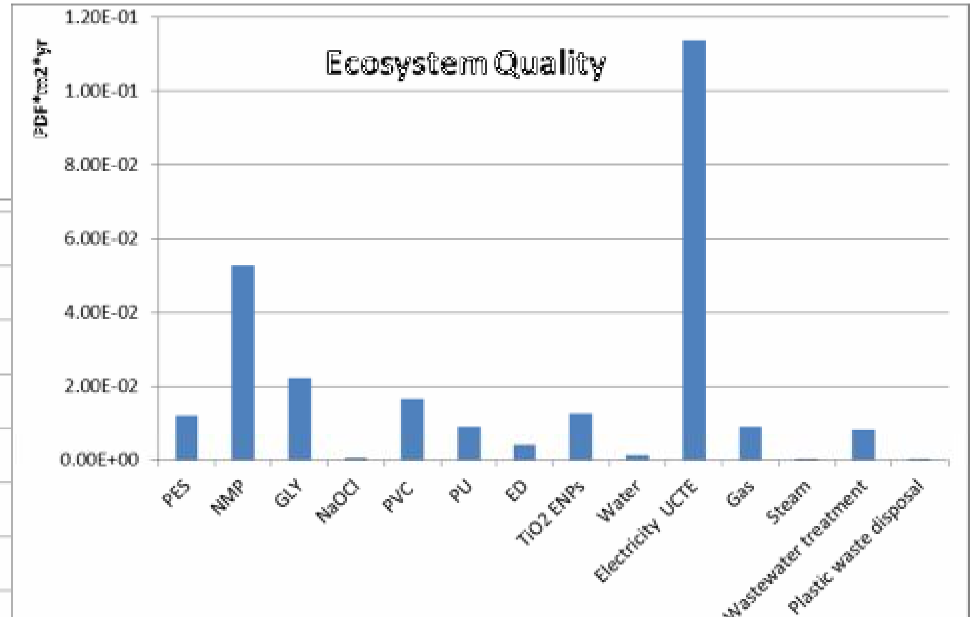
Heavy metals emissions to water

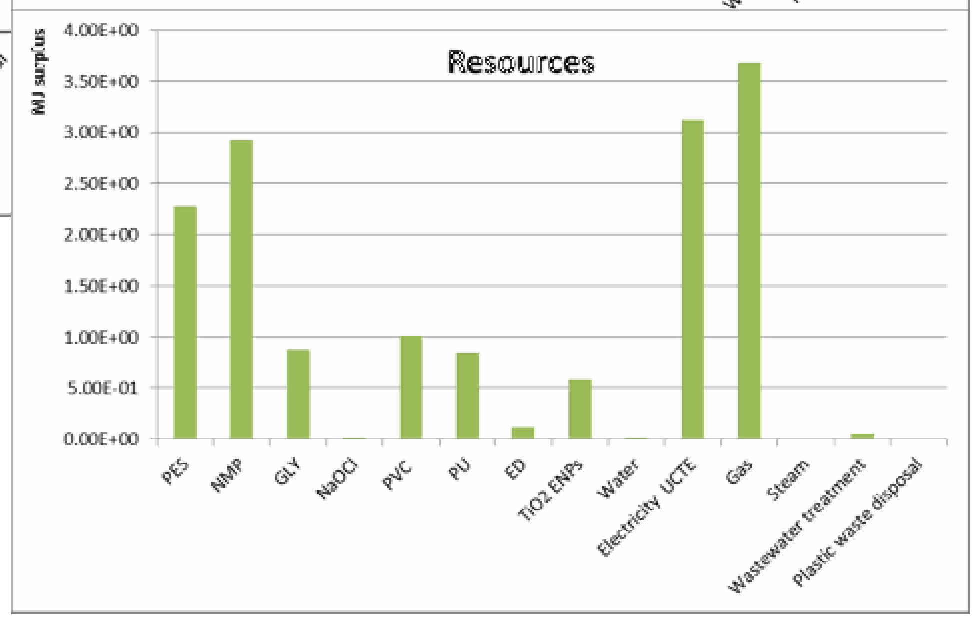


Results

Damage categories

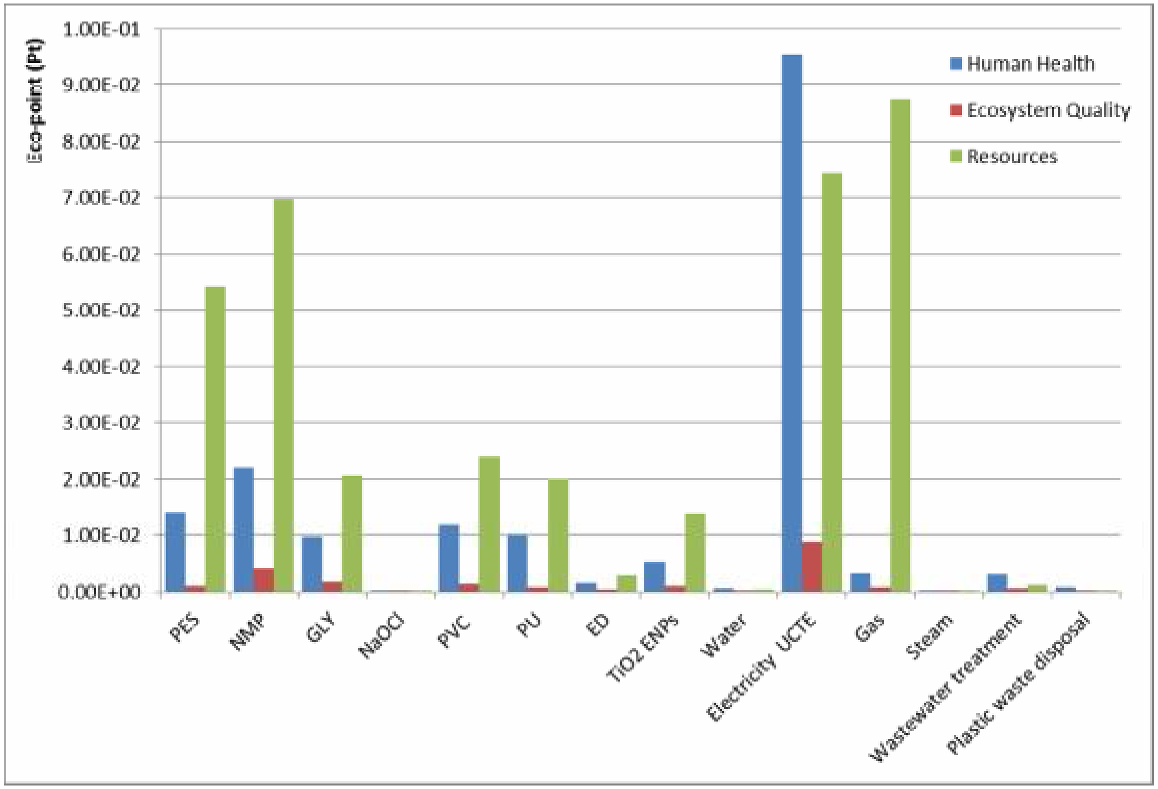






Results

Eco-Indicator '99 normalized results



Results expressed as weighted final score (i.e. Eco-Indicator Point; Pt)

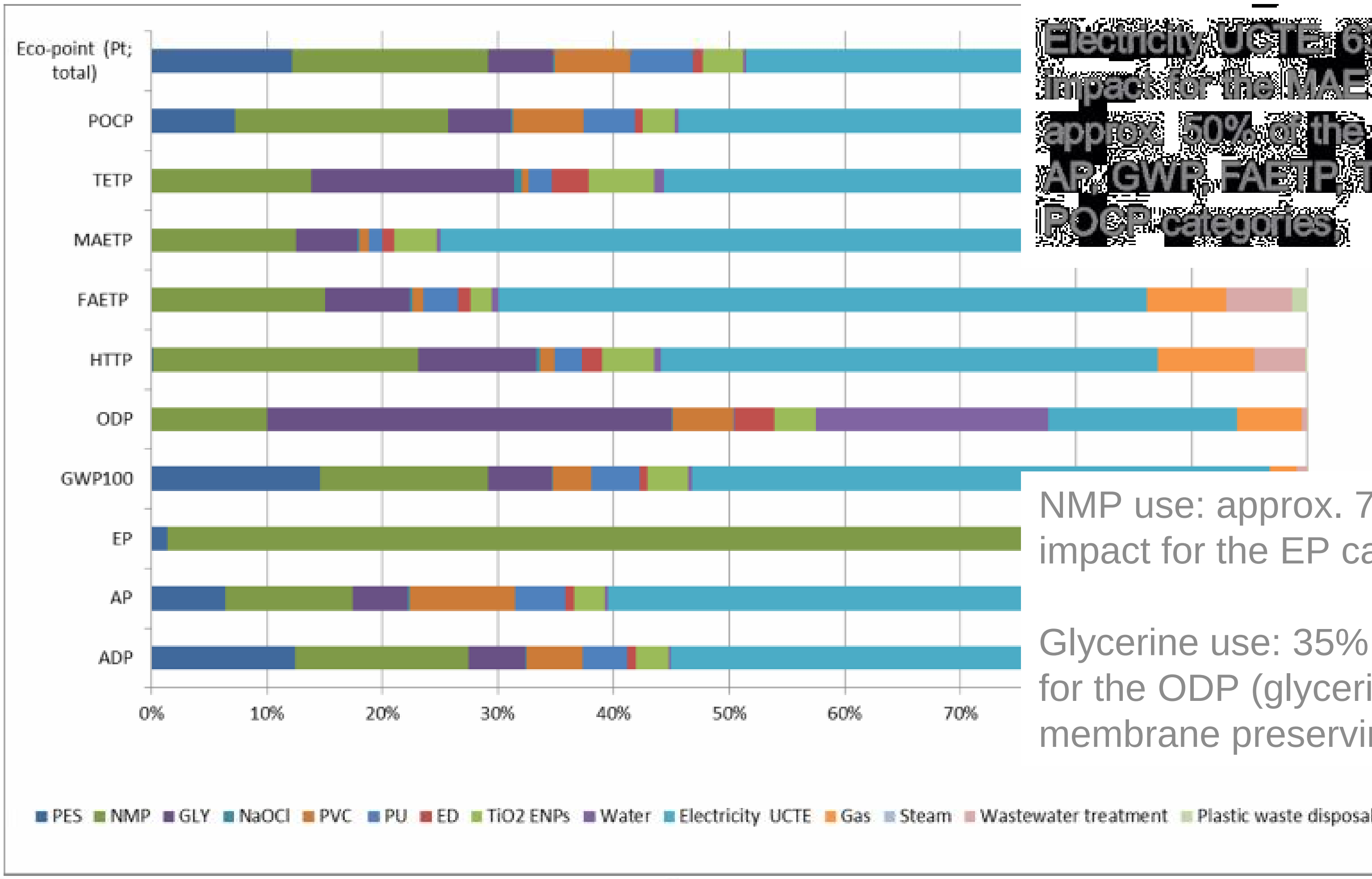
The most damaged categories are R and HH.

For the R damage category, the contribution is due likewise among the electricity, gas, NMP and PES use stages; this confirms the dominance of resources-intensive process in the membrane production.

For the HH damage category, the contribution is mainly due to electricity use stage.

Results

Main contributors to the environmental impacts



Electricity UCTE: 63.5% of the total impact for the MAETP category, and approx. 50% of the overall impact for AP, GWP, FAETP, TETP and the POCP categories;

NMP use: approx. 75% of the total impact for the EP category.

Glycerine use: 35% of the total impact for the ODP (glycerine needed for membrane preserving).

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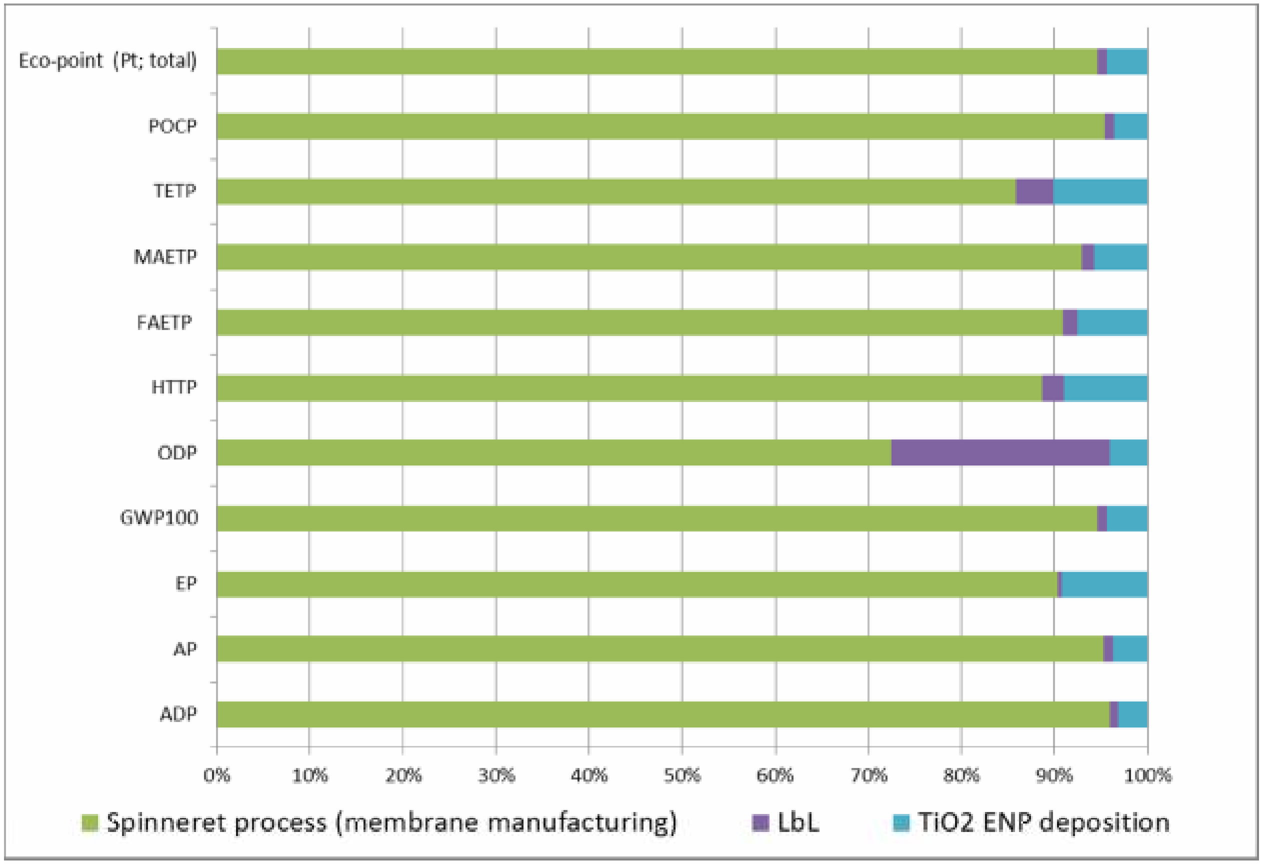
Results

Main contributors to the environmental impacts: aggregated results between membrane manufacturing, LbL and ED processes



The membrane manufacturing has the greatest contribution to all impact categories.

The LbL and ED show a very low percentage of potential effects that look almost negligible compared to membrane production.

Conclusions

- The use of TiO_2 NEPs has a lower environmental impact compared to other stages investigated.
- Membrane manufacturing has the greatest contribution to all categories
- The electricity use stage during the spinneret process is the main contribute to the overall environmental impact
- The Europe energy mix has been taking into account here, where more of the 61 % of the total electricity production is obtained from extraction of fossil fuels and the chemicals release to the environment (e.g. SO_2, NO_x and heavy metals) are the most important emissions contributing to different impact categories.
- NMP and PES production process and gas needed are the most resources-intensive processes.

Final considerations

- The use phase and end of life of membrane are not included: next step will include these phases of life cycle membrane
- The use phase of membrane may be a potential source of ENPs to the environment: release rate ? (*ongoing analysis in NAMETECH to estimate ENPs release during membrane use*)
- Considerable efforts are required in the future to expand available LCI database to cover at least the most important ENPs (e.g. Ag, TiO_2, SiO_2, etc.)
- Consideration of ENPs-related effects in LCIA: how ENPs properties affect characterization of ENPs' toxic and fate within the LCIA? No nanospecific environmental impacts included.
- Performance based indicators for nano-based products: what are environmental benefits (or impacts) in comparison to membrane without ENPs?

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Thank You very much for your attention!

Questions ?

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