Potential methodological gaps and inconsistencies in the use of LCIA methods

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LCIA Method selection for innovative PV

Which criteria for the selection of the proper LCIA Method?

- *Evaluation of the toxicity issue in LCA*
- *Models used for characterization factors calculation*
- *Main issues connected with impacts assessment*
- *Comparison among impact values calculated with several LCIA methods (inorganic compounds and the effects of uncertainty on CFs)*

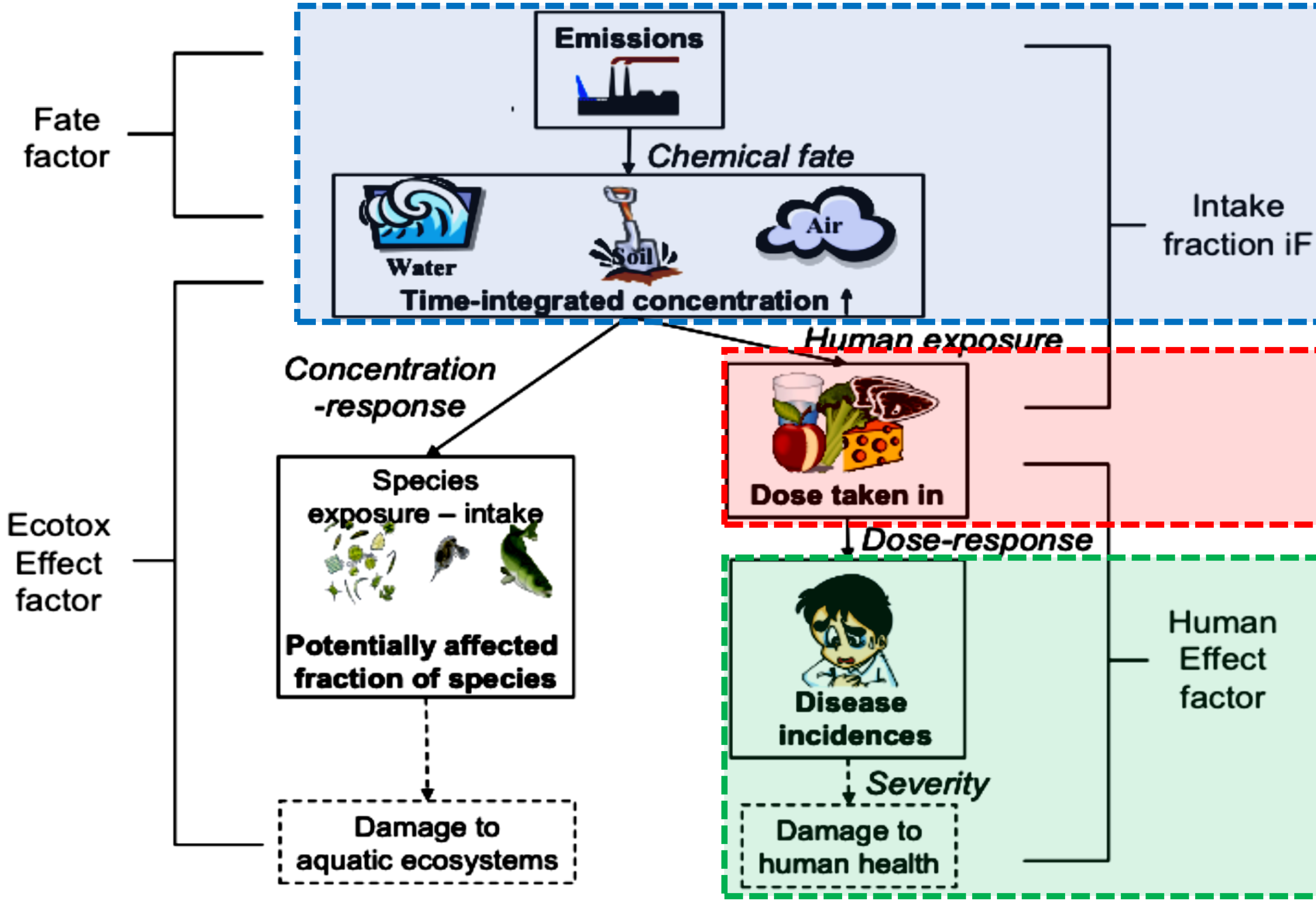
How to model single scoring for endpoint impact assessment?

- *Need for comparative evaluation*
- *Inclusion of additional indicators (CED, Energy Pay-Back Time, IMP, etc…)*

Toxicity Assessment in LCA

$$IS = \sum_i \sum_x CF_{x,i} \cdot m_{x,i}$$

The *Characterization Factor* determines the magnitude of the impact (IS) and is obtained from the product of:



Chemical fate (FF)

- *Distribution of emissions between air, soil and water*

Esposizione (XF)

- *Inalazione, ingestione, contatto etc.*

Effetto sulla salute umana (EF)

- *Midpoint*
- *Endpoint*

Toxicity Assessment in LCA

Issues related to toxicity assessment in LCIA:

- Limited number of substances included in LCIA methods
- Mismatch among CFs in LCIA methods and substances in LCI databases
- Lack of (eco)toxicological data (effects)
- Lack of transparency of the models used and/or accessibility of data
- Complex impact mechanisms and results obtained that are difficult to interpret and compare
- High uncertainty of the results

(Eco)toxicological impacts are often excluded from LCA studies

REACH USEtox®


European Commission

JRC TECHNICAL REPORTS

Supporting information to the characterisation factors of recommended EF Life Cycle Impact Assessment methods

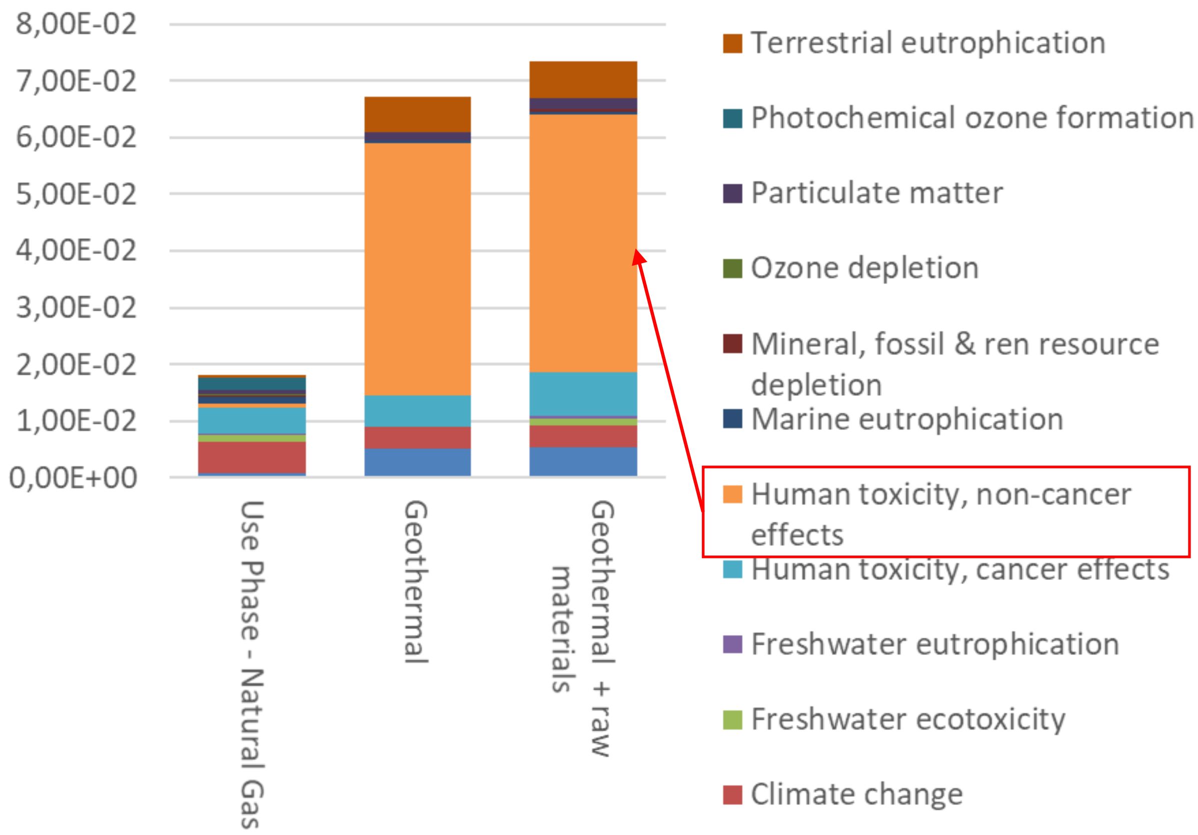
Version 2
from ILCD to EF 3.0

Fazio, S. Biganzioli, F. De Laurentiis, V., Zampori, L., Sala, S. Diaconu, E.

2018

The inorganics issue from the LCA perspective

ILCD 2011 – single score



HTnc contributes about 60-65% of the total impact of geothermal energy

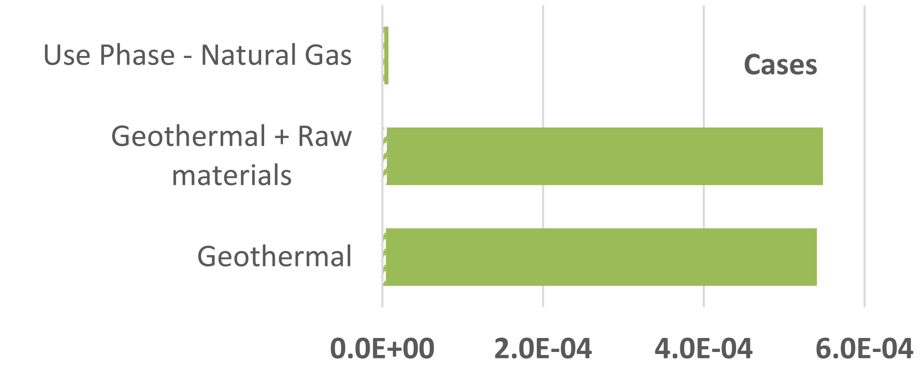
Hg determines 99% of the impact in the HTnc category

Consumption of chemicals does not significantly affect the results

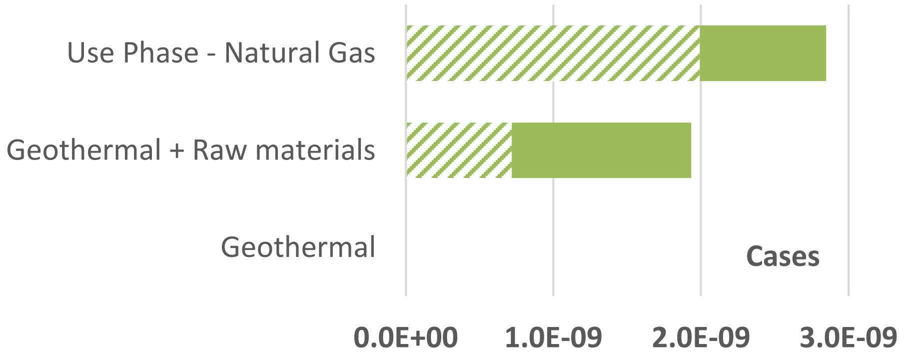
The inorganics issue from the LCA perspective

- Sono evidenti le differenze, anche in termini relativi, che i diversi metodi generano.
- Lo USEtox restituisce un punteggio per *Geo* quasi 2 ordini di grandezza superiore al *Nat Gas*, ma limitando l'analisi ai CF raccomandati si ottiene un valore totalmente opposto.

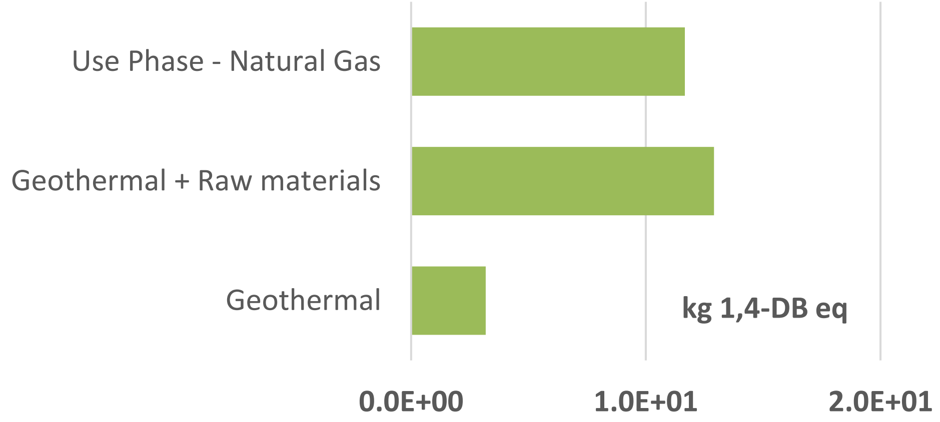
USEtox 2



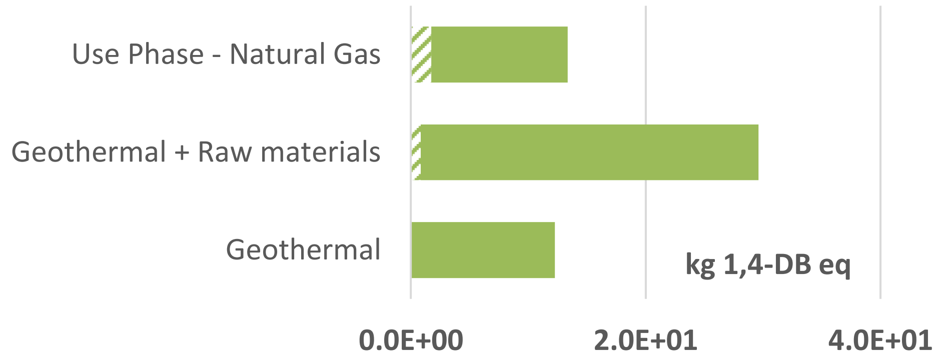
USEtox 2 (recommended only)



CML-IA Baseline



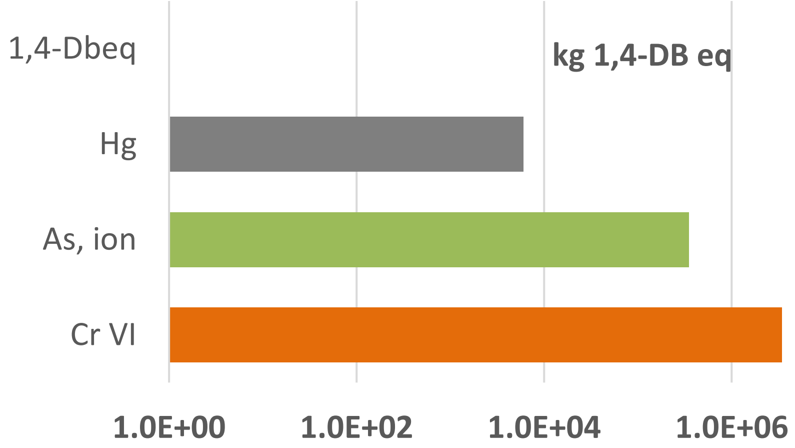
ReCiPe2016 Midpoint (H)



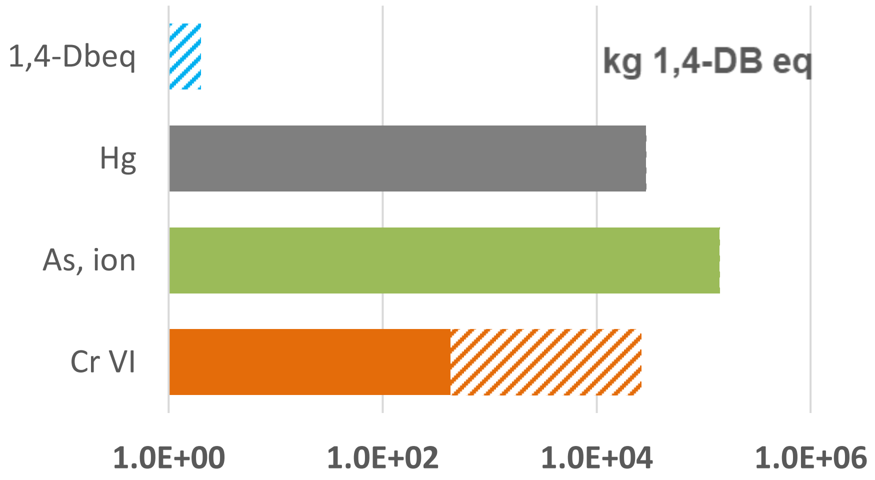
Human toxicity, cancer **Human toxicity, non-cancer**

Representative substances of geothermal power plants emissions (Hg and As) and not (Cr VI and 1,4-DB)

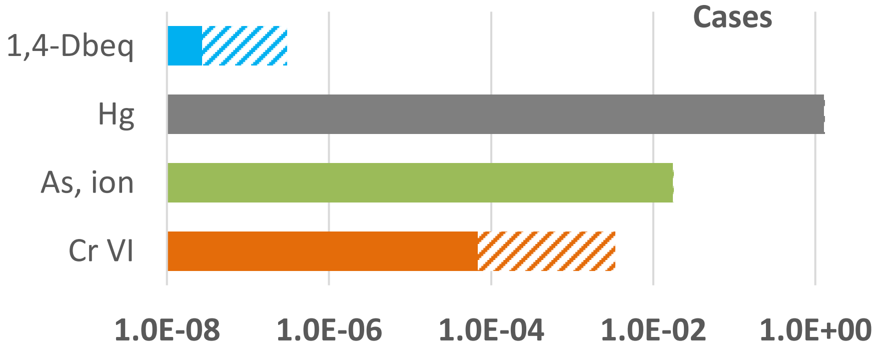
CML-IA



ReCiPe 2016 midpoint H



USEtox 2

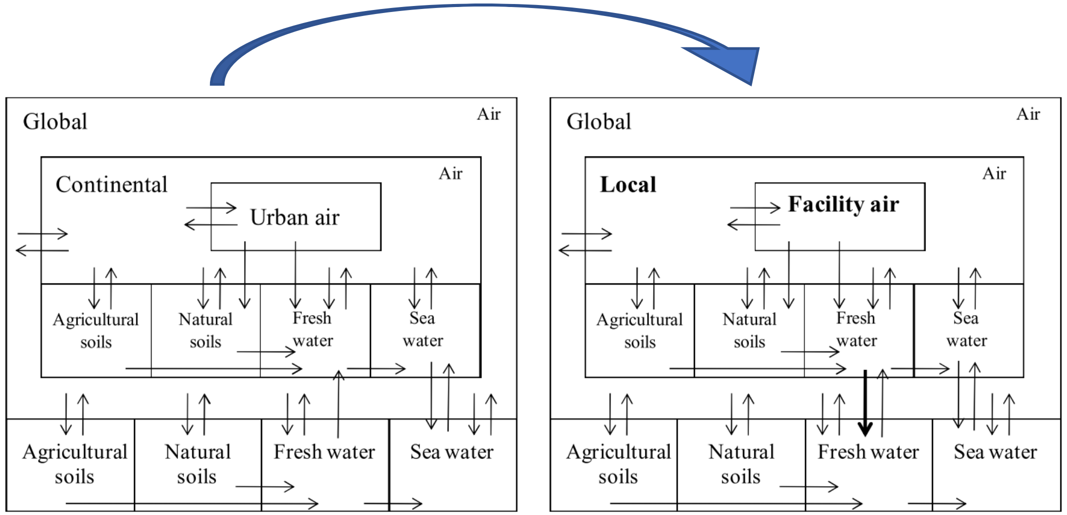


The relationships among CFs of selected substances show the significant variability among LCIA methods

Toxicity Assessment in LCA

As stated in the USETox method documentation:
"It should be stressed that the characterization factors are useful for a first-tier assessment. In case a substance appears to dominantly contribute to the impact scores for toxicity, it is recommended to verify the reliability of the chemical-specific input data for this substance and to improve the data whenever possible"

Could be possible to improve the characterization of metals by adapting the global behaviour of the method in order to obtain a local and best-fitting box.



The lead issue from the LCA perspective

Despite the relatively low calculated potential impact of lead, the presence of such metal highly contributes to the toxicity-related environmental categories.

To perform a reliable LCA study that could support in the development of robust evaluation of the eco-toxicological impact associated to the production, use and end of life of PSCs, some **issues need to be addressed**:

- The **lack of primary data;**
- The **absence of a specific characterization factor for PbI_2**;
- The **inherent high uncertainty of life cycle impact analysis methods**.

The main goal of LCA of perovskite technology is **to investigate** the environmental impact of this technology and **to support** the sustainable industrial development, suggesting feasible solutions and suitable risk mitigation practices.

- Maranghi S, Parisi ML, Basosi R and Sinicropi A. Environmental Profile of the Manufacturing Process of Perovskite Photovoltaics: Harmonization of Life Cycle Assessment Studies. *Energies* 2019, 12, 3746, https://doi.org/10.3390/en12193746
- Maranghi S, Parisi ML, Basosi R and Sinicropi A. The critical issue of using lead for sustainable massive production of perovskite solar cells: a review of relevant literature. *Open Res Europe* 2021, 1:44, https://doi.org/10.12688/openreseurope.13428.1
- Parisi, M.L., Sinicropi, A. Closing the loop for perovskite solar modules. *Nat Sustain* 2021,4, 754–755, https://doi.org/10.1038/s41893-021-00735-1

The lead issue from the LCA perspective

- From the toxicological **point of view, Pb and Pb-based compounds employed and eventually released by PSCs are extremely dangerous and toxic for living organisms**. Strong effort should be put into the further investigation and characterization of fate, exposure and potential toxicity of all Pb-based compounds used and that could be emitted during the whole life cycle of PSC devices.
- On the contrary, **from the LCA perspective Pb shows a quite limited burden on PSCs' environmental profile**, mainly due to the small Pb quantity involved and the limited impact of the Pb metal's production process.
- **According to the main outcomes of LCA on PSC**, the replacement of some raw materials, the **reduction of some chemical compounds' consumption**, the **improvement of energy requirements**, and the **implementation of a safe end-of-life phase** are the **crucial environmental hotspots** that need to be addressed to accomplish industrialization and mass production.
- **Deepen and more detailed LCA studies focusing on the life cycle of Pb-based compounds employed are necessary to evaluate the real sustainability of Pb-based PSCs**.
- At the same time, widening the perspective to mitigate risks along the whole value chain, for the technology to have the **chance to enter the PV market firmly**, **manufacturer companies should put effort to:**
  - **guarantee the safeness of the PSCs manufacturing phases work environment;**
  - **develop reliable encapsulation techniques to prevent Pb-leakage during the transportation and use phases;**
  - **implement a harmless and controlled end-of-life management procedures.**

Single scoring

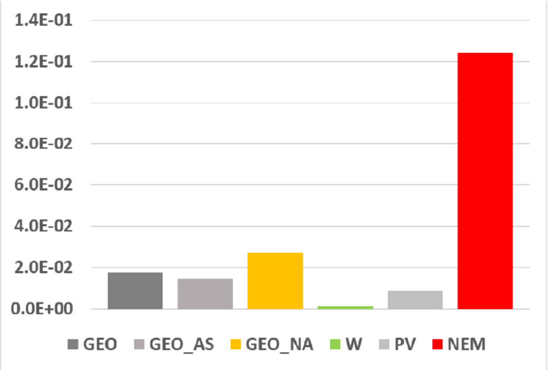
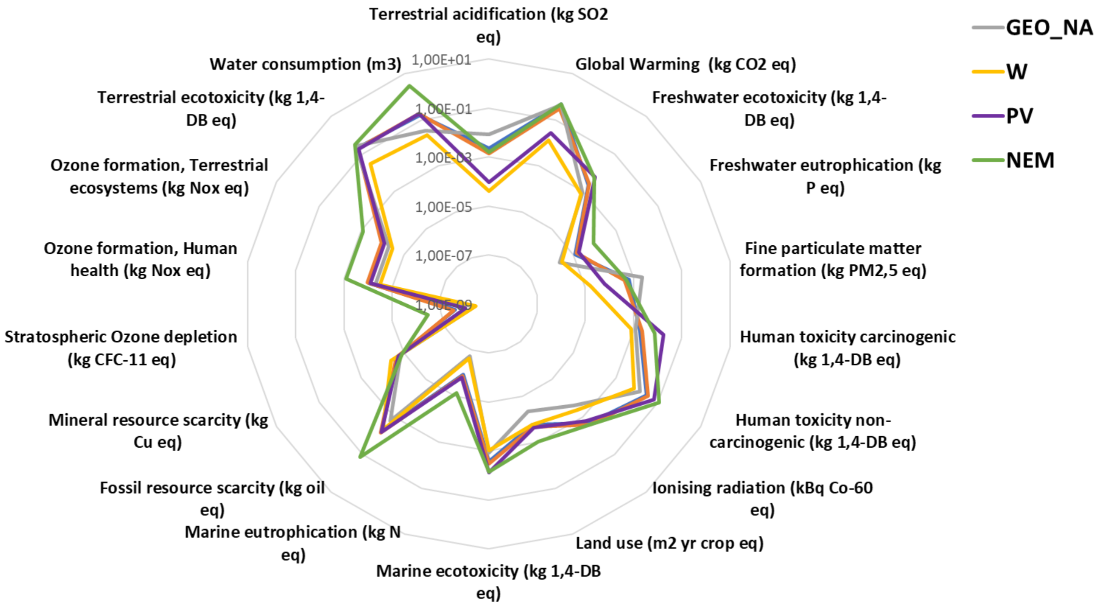
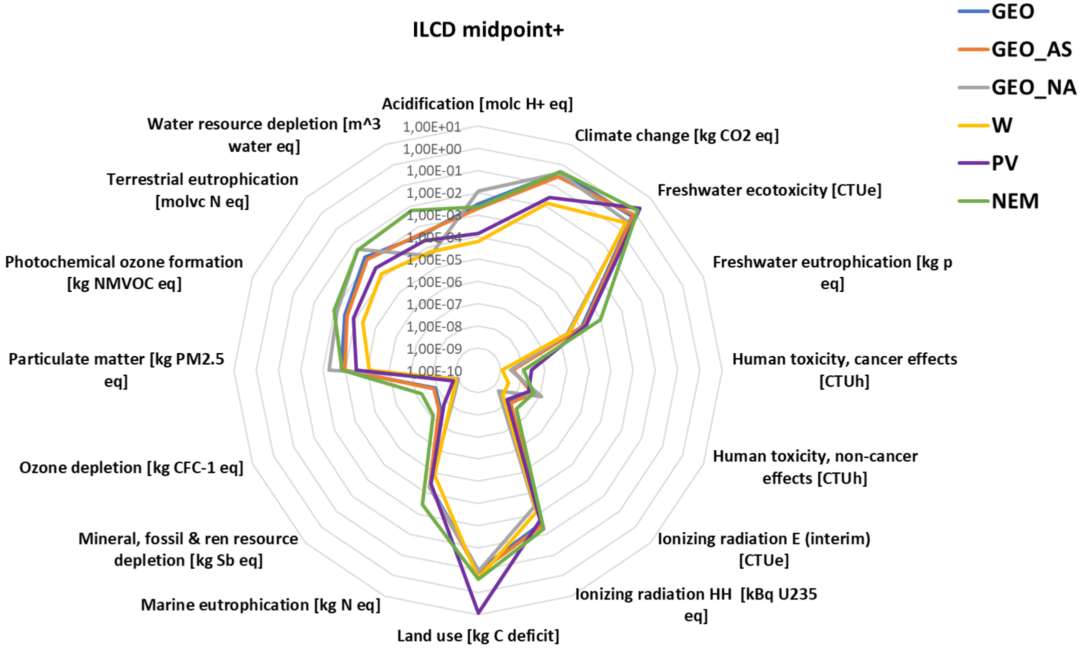


Figure 14. Weighted results calculated with the ReCiPe 2016 method (Eco-points/kWh).





Basosi R., Bonciani R., Frosali D., Manfrida G., Parisi M.L., Sansone F. (2020). Life Cycle Analysis of a Geothermal Power Plant: Comparison of the Environmental Performance with Other Renewable Energy Systems. SUSTAINABILITY, 12, 2786.

Grounds for Thoughts….

How to select the LCIA method?

- *Geographical context, standard method or selection of impact indicators, inclusion of additional indicators, etc..*
- *A state-of-the-art literature review of LCIA methods used should be updated*
- *Single scoring, interpretation and communication*