Ex-ante LCA on an emerging electro-mass separation technology: The importance of the background system

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INTRODUCTION

A new treatment process for Class F fly ashes is being developed, using a proprietary technology, called the Dusty Cloud Separator (DCS), to separate the fly ash into several fractions based on their particle size, with the ultra-fine fly ashes being used to act as a substitute for silica fume in Ultra-High-Performance Concrete (UHPC) [1]. In order to assess the environmental impact of this technology when it is fully developed, a consequential LCA study was performed on the technology using an ex-ante approach [2].
The goal of this study is to refine the previous assessment. First, by incorporating potential changes that may have occurred to the cement industry and its background system by the time the innovative technology is released. This will be done using data from a previous study which looked at how the production of clinker and the electricity market will develop over the coming decades [3]. Second, by incorporating potential uses of the coarse fraction into the assessment. In the previous study the coarse fraction was landfilled as it was too coarse to be used in cement. Since then, tests have been performed, which indicate that the coarse fraction can be used in firebrick clay to (partially) substitute sand [4] and that grinding the coarse fraction to the medium particle size will allow it to be used to substitute cement.

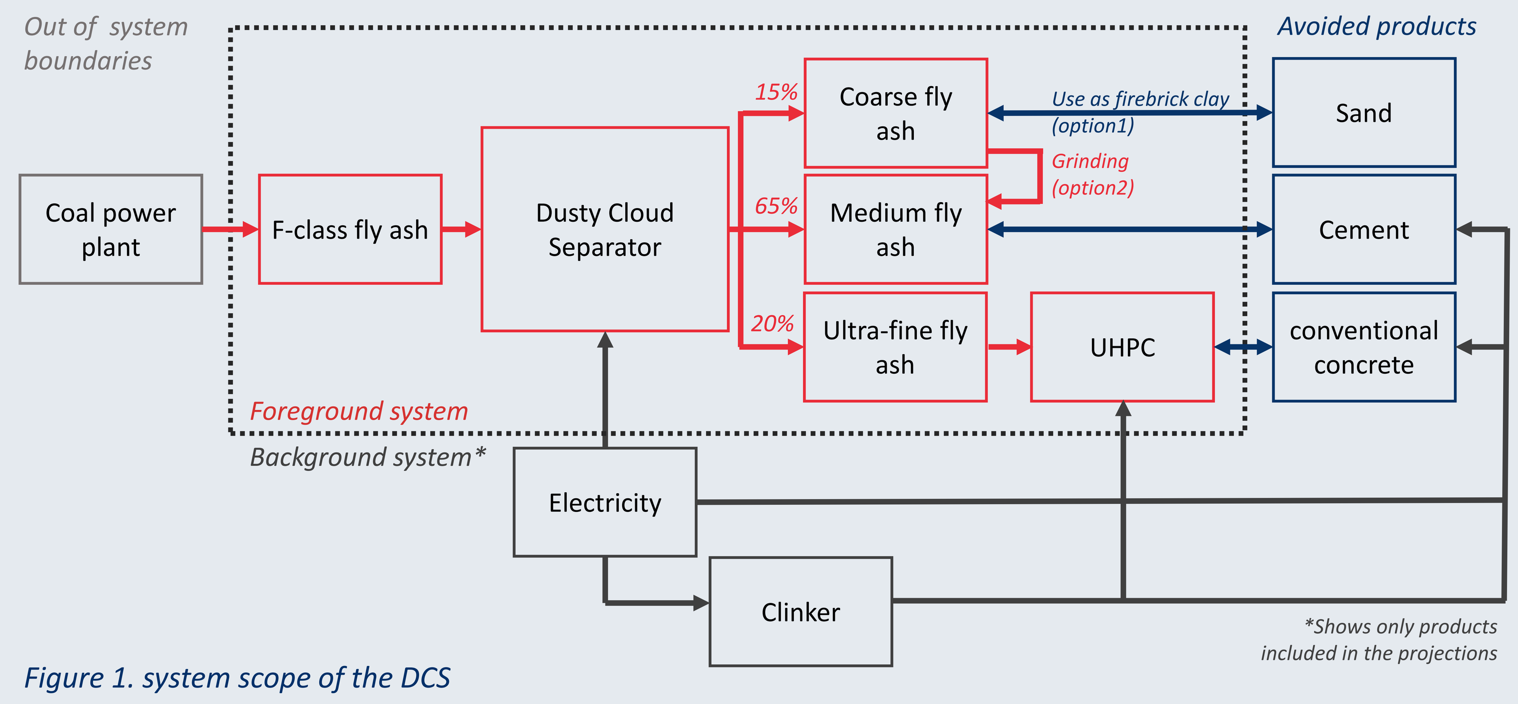

Figure 1. system scope of the DCS

Projections on the background system

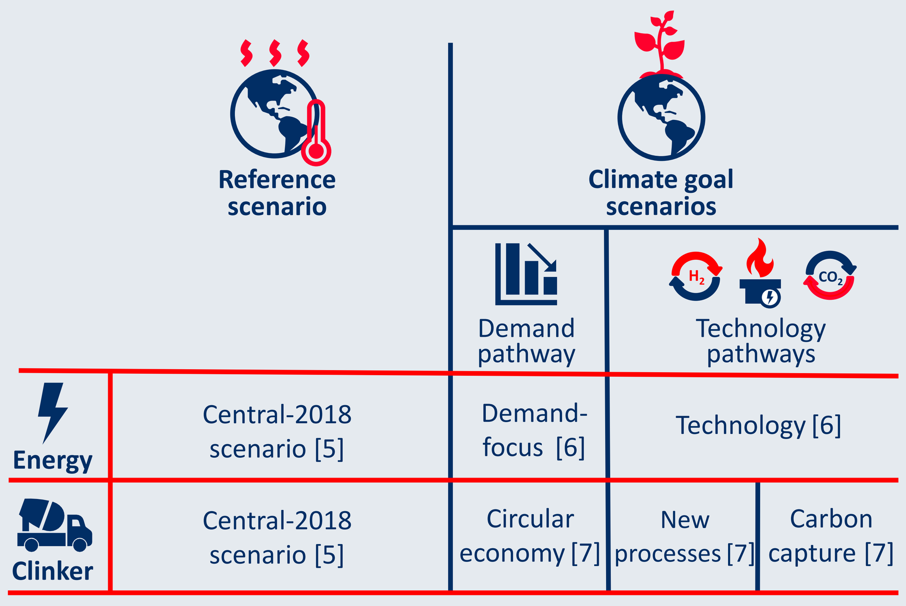

Figure 2. explorative scenario approach

- Projections for electricity and clinker were integrated in the assessment:
  - Clinker has a large influence on the environmental benefit of the fly ash
  - Electricity is used for:
    - cement kilns (future)
    - DCS
    - Grinding of the coarse fraction
- Uncertainty of the future is handled by adopting an explorative scenario approach in which multiple potential futures are assessed (see figure 2.)

FUTURE MARGINAL MIX

Electricity

- Wind energy is an important marginal tech in all scenarios and throughout the coming decades
- Carbon capture only shows up in the reference scenario

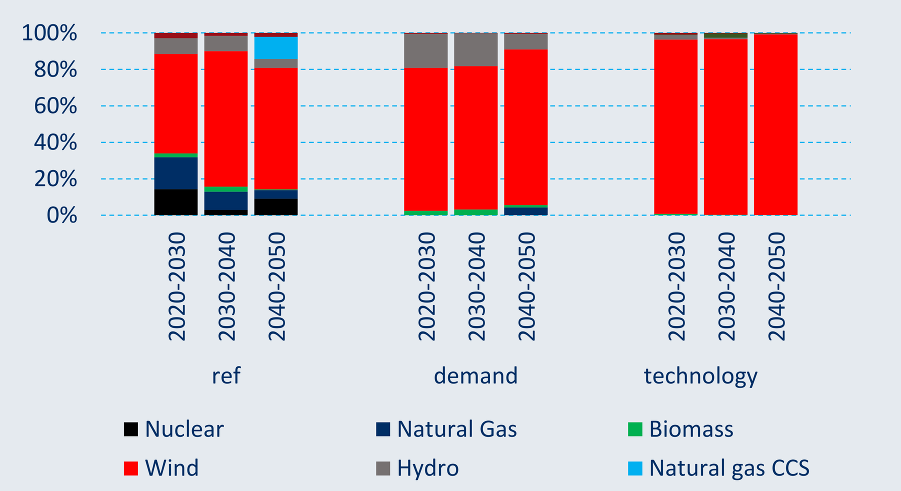

Figure 3. electricity marginal mix

Clinker

- Fossil fuels remain important in the reference scenario
- Biomass becomes more important in the climate goal scenarios but is a constraint source (left out of marginal mix)
- Electric kilns and carbon capture will both become important technologies

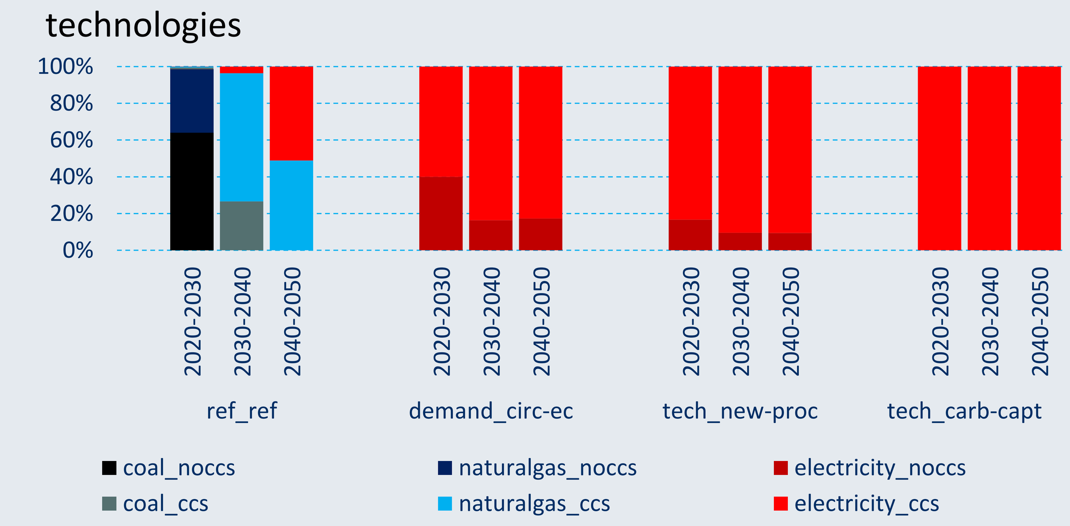

Figure 4. clinker marginal mix

LCA-METHODOLOGY

The goal of this study is to assess the future environmental impact of fly ash undergoing classification using the DCS (see figure 1) against the incumbent practice in which the fly ash is directly used in cement. The functional unit is therefore the treatment of 1 t of Class F fly ash. As stated earlier, a consequential approach is chosen for this study. Ecoinvent 3.6 is used for the life cycle inventory. The assessment is performed using Recipe 2016 v1.1.

UHPC VS CONVENTIONAL CONCRETE (CC)

The ultra fine fraction can be used instead of silica fume to produce UHPC. As silica fume is a constraint product with low availability it was assumed that any addition of ultra fine fraction onto the market would not result in a replacement of silica fume, but instead in an increase of UHPC production. The potential environmental benefit gained from using UHPC compared to conventional concrete is assessed and linked to the ultra fine fraction which allowed for the production of the UHPC. The environmental benefit is calculated using a simplistic version of a bridge as a case study [8]

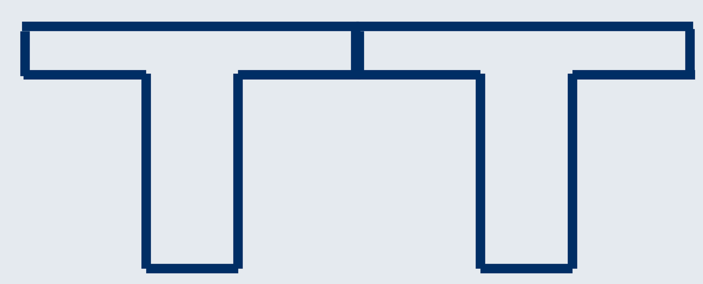

Figure 5. cross section bridge using CC

- 36,7%

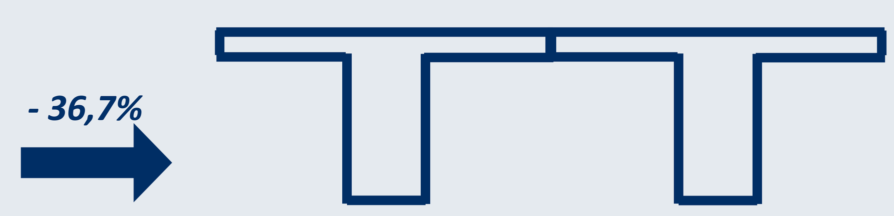

Figure 6. cross section bridge using UHPC

RESULTS

Untreated fly ash vs DCS treatment (see figure 7)

- DCS treatment provides a greater environmental benefit than the use of untreated fly ash and this for all scenarios
- Results on the untreated fly ash are more varied throughout the scenarios
- The impact of the DCS itself is negligible

Coarse fraction: option 1 vs 2 (see figure 8)

- The impact of grinding the coarse fraction is heavily outweighed by the environmental benefit of cement substitution
- Option 2 provides a greater environmental benefit than option 1 and this for all scenarios
- The environmental benefit of option 2 is varies significantly throughout all scenarios

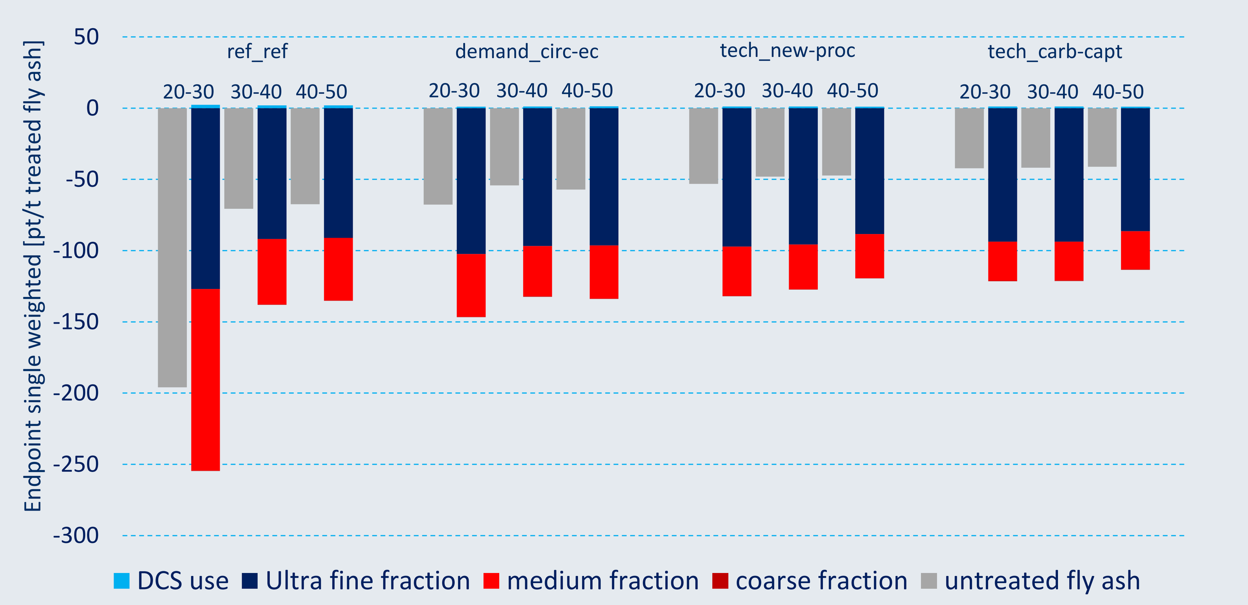

Figure 7. LCIA: untreated fly ash vs DCS treatment (using option 1 for the coarse fraction)

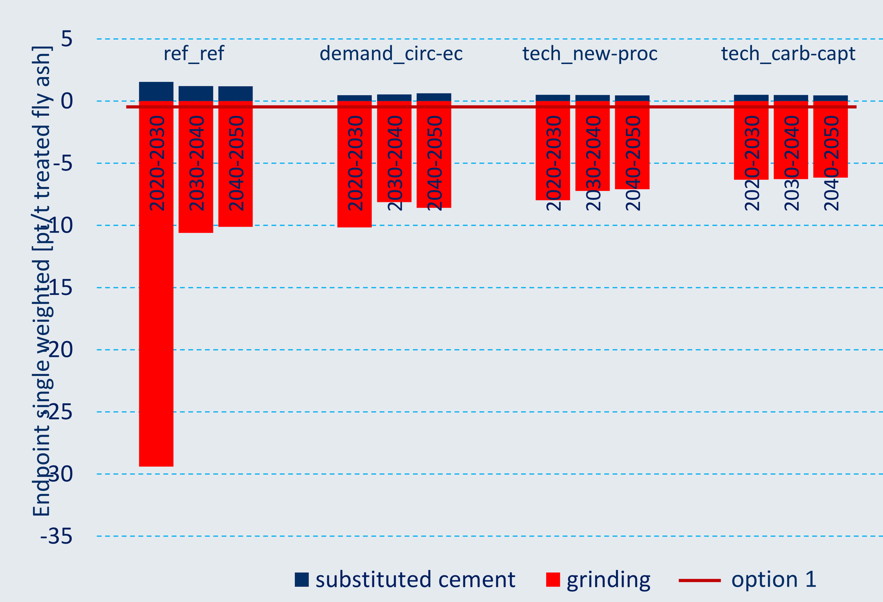

Figure 8. LCIA: comparing valorization options for the coarse fraction

DISCUSSION

- The ultra fine fraction had the most influence on the results
- The environmental benefit of UHPC an vary greatly depending on the structure chosen
- Steel had a large influence on the environmental benefit of UHPC thanks to the case study
- Results of the DCS treatment stayed more constant because of the influence of steel
- The collection efficiency of the ultra fine fraction might change when upscaling the DCS.
- Projections on the background system had a noticeable impact on the results

Conclusions

- The DCS treatment provides an environmental benefit to the incumbent practice
- Potential changes to the background system should be taken into account when performing an ex-ante LCA
- Future work will:
  - Take into account changes to the DCS using data from upscaled versions modelled with CFD software
  - Incorporate potential changes to steel production into the LCA
  - Investigate for a more consistent way to compare concrete with different characteristics

REFERENCES

1) Ruben Snellings et al, 2019. Pozzolanic reactivity of size-classified siliceous fly ashes. Proceedings of 2nd International Conference of Sustainable Building Material
2) Maes B., Buyle M., Audenaert, A., Craeye, B., 2021. Enhanced fly ash use in concrete: Ex-ante LCA on an emerging electro-mass separation technology, jclepro.2021.128081
3) Maes B., Audenaert A., Craeye B., Buyle M., 2021. Consequential ex-ante life cycle assessment on clinker production in the EU: How will the future influence its environmental impact?, j.clet.2021.100076
4) Yörük C.R., Gregor A., Snellings R. TALTECH, VITO 2020. Report on the valorisation of the coarse fraction as composite or bitumen filler.
5) Leonidas M., Tobias W., Frederik N., Máté R., 2019. The POTEnCIA Central scenario: an EU energy outlook to 2050.
6) CLIMACT, 2018. 2050 scenario analysis using the EU CTI 2050 Roadmap Tool. European Climate Foundation.
7) Material Economics, 2019. Industrial Transformation 2050 - Pathways to Net-Zero Emissions from EU Heavy Industry.
8) Ingrid Lande Larsen et al 2017 IOP Conf. Ser.: Mater. Sci. Eng. 245 052096

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