Supplementary Information 1 (SI-1)

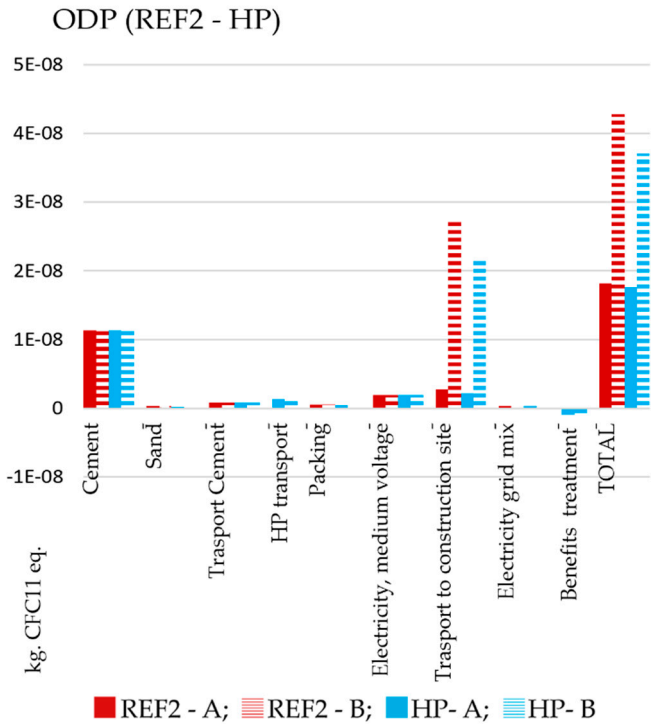
Life Cycle Assessment of mortars with fine recycled aggregates from industrial waste: evaluation of transports impact in the Italian context

Marco D'Orazio, Elisa Di Giuseppe, and Marta Carosi

LCA Analysis – Local scenario

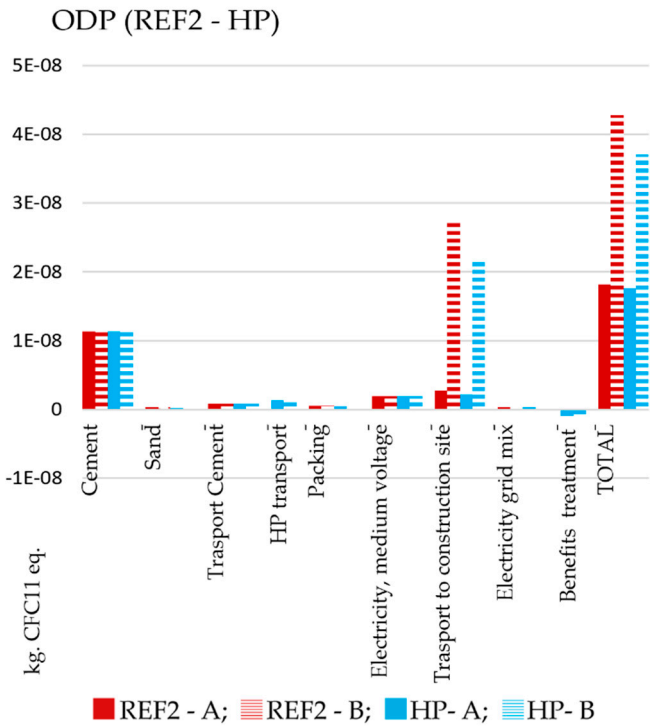
1. Depletion potential of the stratospheric Ozone Layer (ODP)

The comparison of Depletion potential of the stratospheric Ozone Layer (ODP) in both scenarios (A and B) is shown in



(**a**) (**b**)

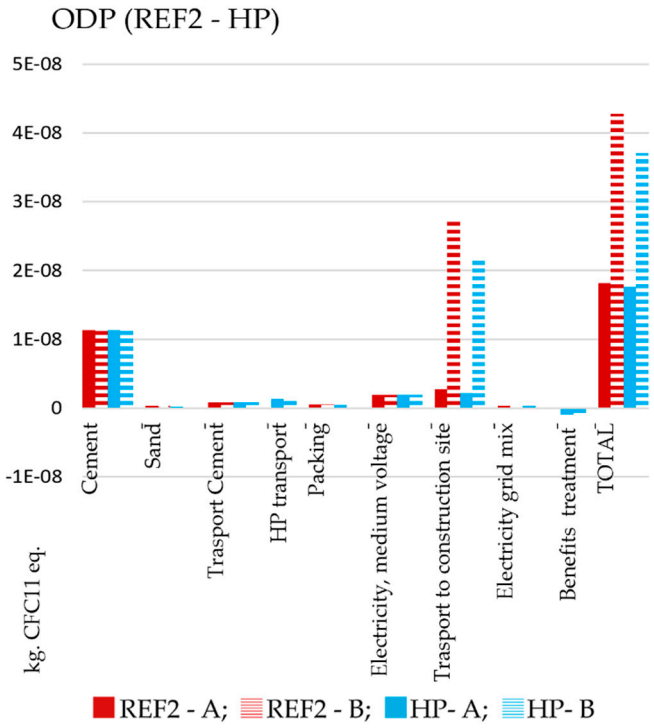
Figure S1 (a) for REF1 and DELTA mortars; and in



(**a**) (**b**)

Figure S1 (b) for REF2 and HP mortars.

In general, DELTA and HP mortars results always better performing compared to their reference mortars made with raw materials (respectively REF1 and REF2). ODP results of DELTA mortar are 18% lower compared to the reference mortar REF1 in scenario A and of 22% lower in scenario B. HP mortar (



(**a**) (**b**)

Figure S1 (b)) reduces ODP of 3% in scenario A and 13% in scenario B compared to mortar REF2.

Compared to scenario A, Scenario B generates an ODP increase of 136% for REF1 and REF2, of 124% for DELTA and of 111% for HP.

In this impact category, the incidence of transport from mortar factory to construction site is very relevant: in B scenarios it is even higher than that of cement. Indeed, for REF1 and DELTA, transportation process in module A4 affects the total ODP for more than 14% in scenario A, but more than 62% in scenario B. Likewise,

for REF2 and HP, the transport to construction site affects total ODP for more than 12% in scenario A and more than 58% in scenario B.

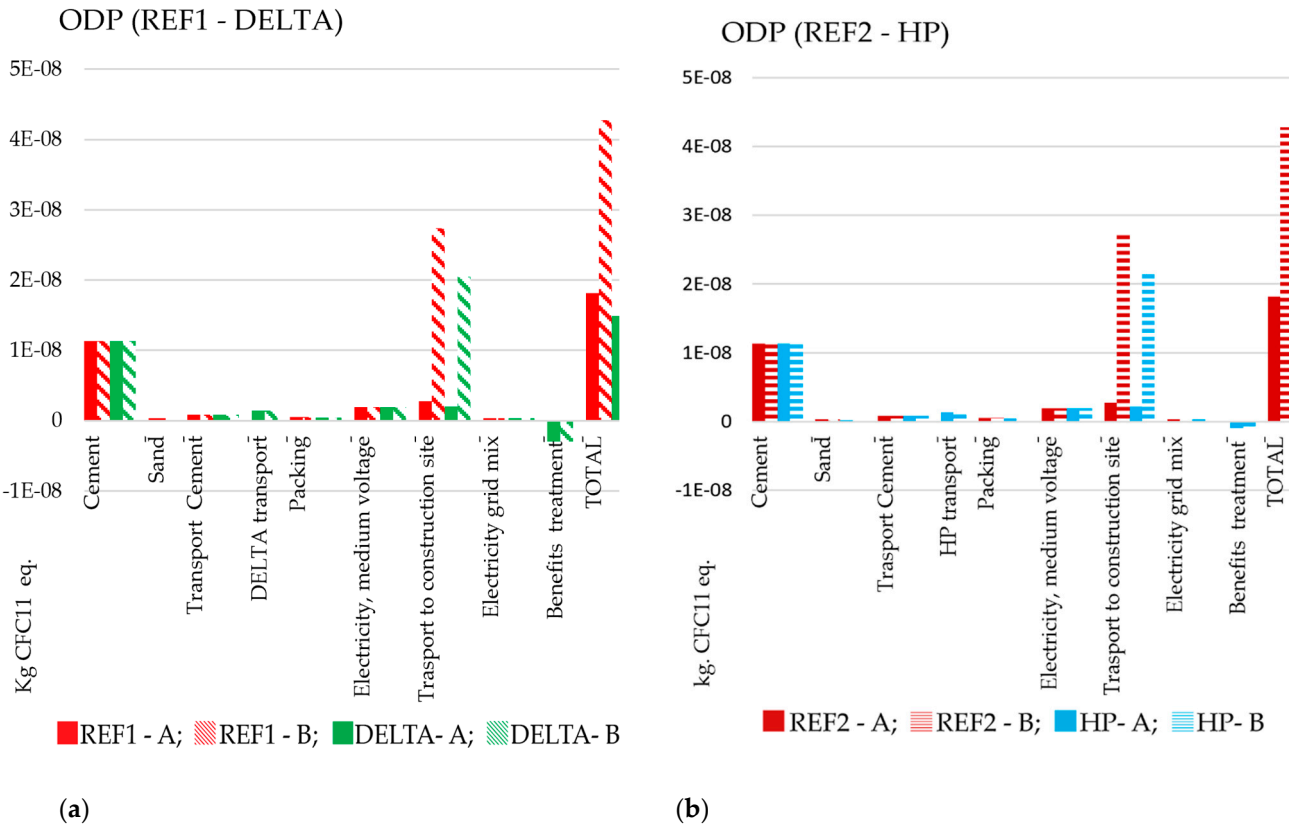


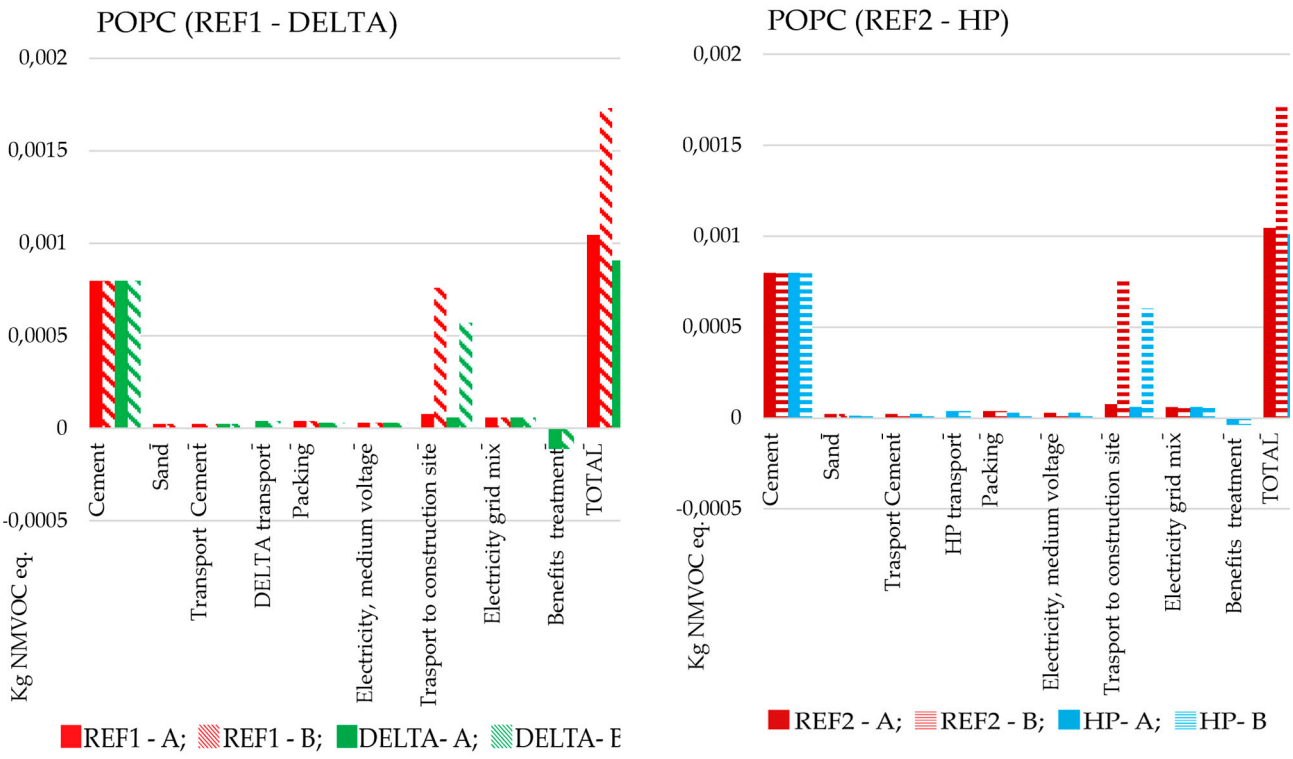
Figure S1. Depletion potential of the stratospheric Ozone Layer (ODP) of: (a) REF1 and DELTA mortars; (b) REF2 and HP mortars.

2. Formation potential of tropospheric ozone (POCP)

The comparison of formation potential of tropospheric ozone (POCP) in both scenarios (A and B) is shown in Figure S2 (a) for REF1 and DELTA mortars and in Figure S2 (b) for REF2 and HP mortars.

In terms of POCP, DELTA and HP mortars results always better performing than their reference mortars made with raw materials (respectively REF1 and REF2). POCP of DELTA mortar is 13% lower compared to that of reference mortar REF1 in scenario A and 18% lower in scenario B (Figure S2 (a)), while HP mortar reduces POCP of 3% in scenario A and 10% in scenario B, compared to mortar REF2 (Figure S2 (b)).

Compared to scenario A, scenario B generates an increase in POCP of 65% for REF1 and REF2 mortars, of 56% for DELTA and of 46% for HP. However, in this case, the incidence of cement is always the highest, in all considered mixtures and scenarios (between 46% and 88%).

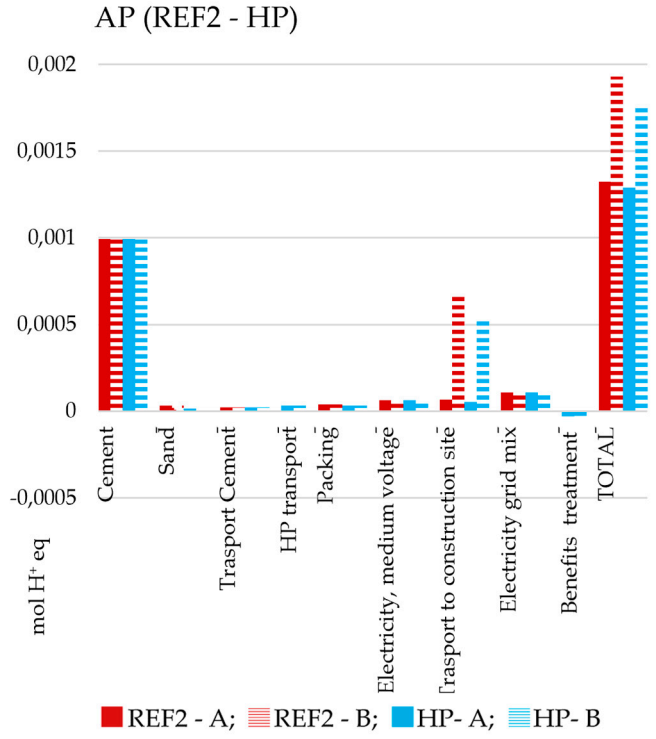


(**a**) (**b**)

Figure S2 Formation potential of tropospheric ozone (POCP) of: (**a**) Mortar REF1 and DELTA; (**b**) Mortar REF2 and HP.

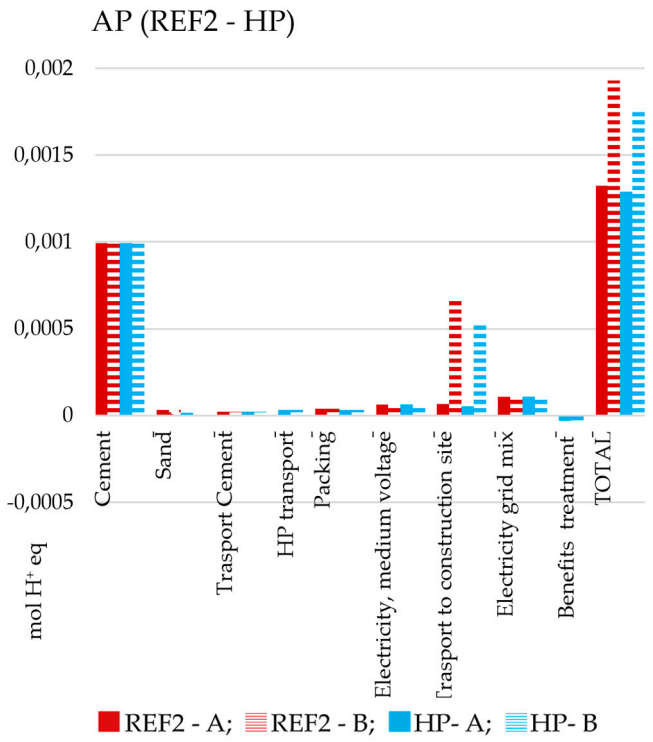
3. Acidification Potential (AP)

The comparison of Acidification Potential (AP) in both scenarios (A and B) is shown in



(**a**) (**b**)

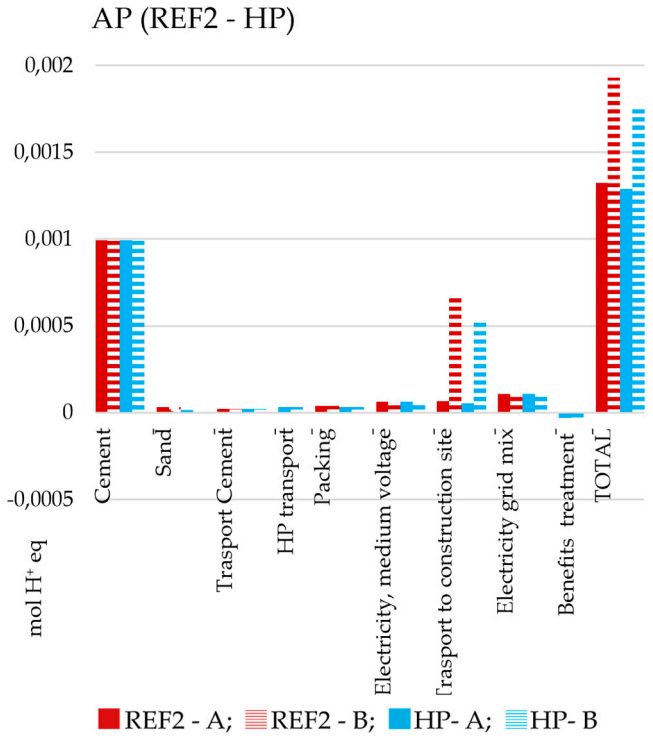
Figure S3 (a) for REF1 and DELTA mortars, and in



(**a**) (**b**)

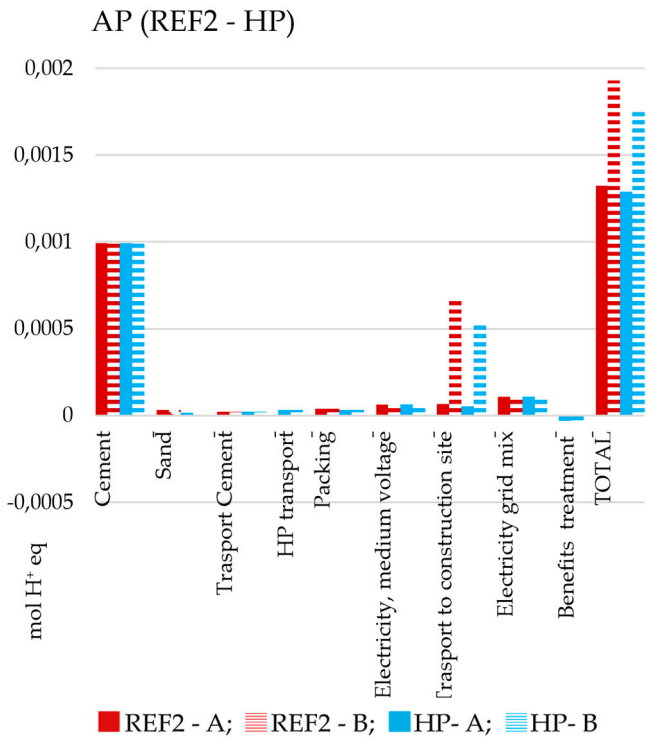
Figure S3 (b) for REF2 and HP mortars.

In terms of AP, DELTA and HP mortars perform slightly better than their reference mortars made with raw materials (respectively REF1 and REF2). AP of DELTA mortar is 9% lower compared to that of REF1 in scenario A and 14% lower in scenario B (



(**a**) (**b**)

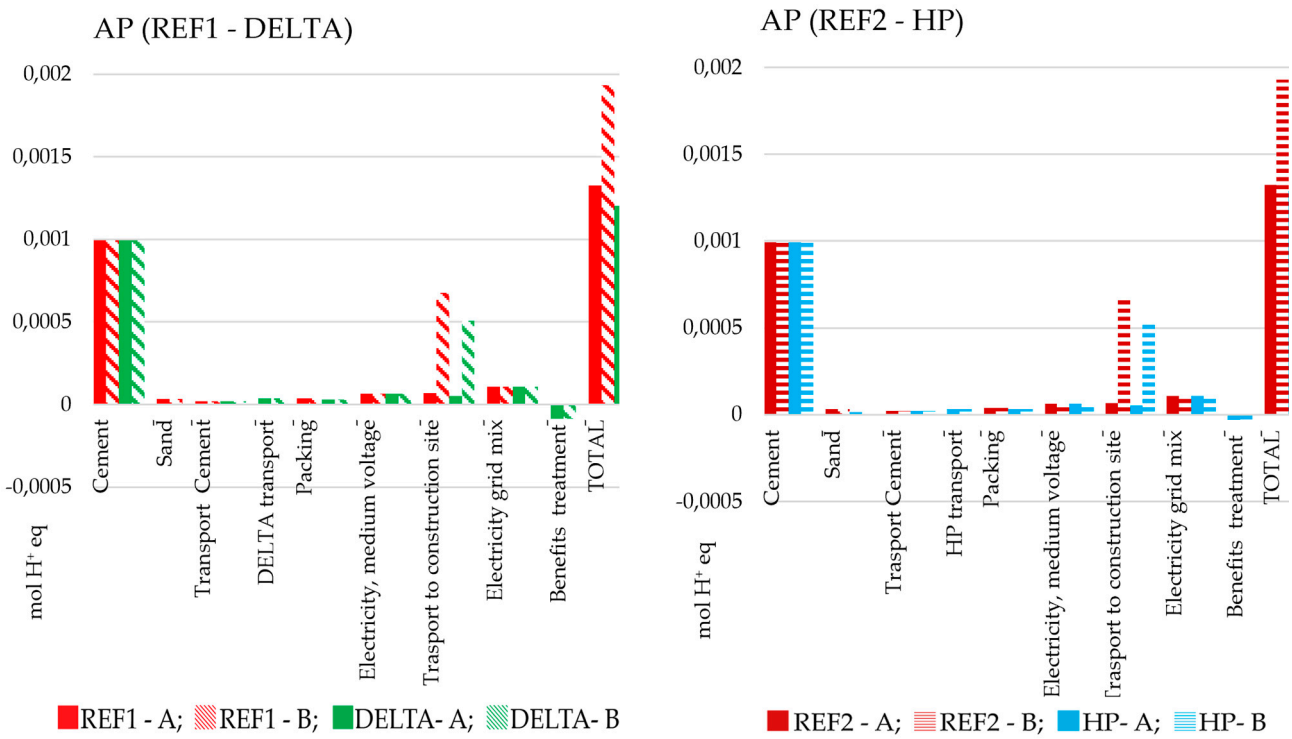
Figure S3 (a)), while HP mortar reduces AP of 3% in scenario A and of 10% in scenario B, compared to REF2 mortar (



(**a**) (**b**)

Figure S3 (b)). Compared to scenario A, scenario B generates an increase in AP of 46% for REF1 and REF2, of 28% for DELTA mortar and of 37% for HP mortar.

However, in this case, the incidence of cement is always the highest, in all considered mixtures and scenarios (between 51% and 83%).

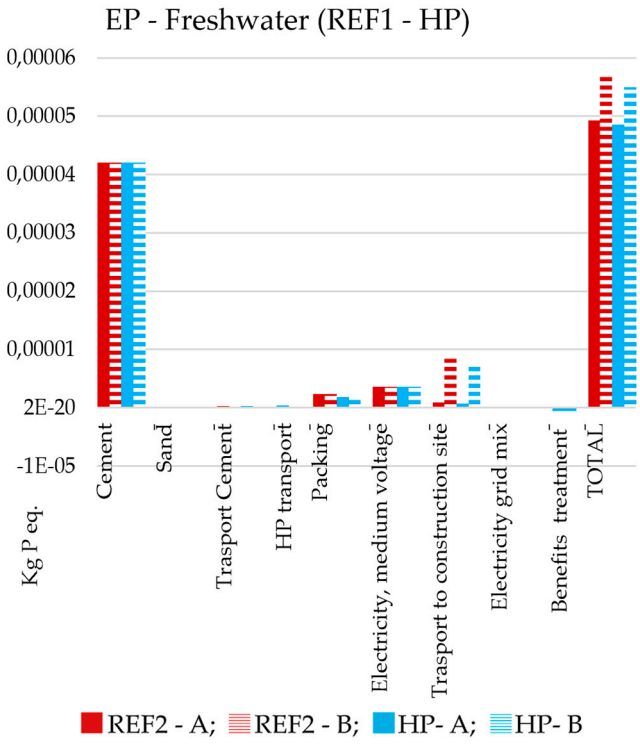


(**a**) (**b**)

Figure S3. Acidification Potential (AP) of: (**a**) Mortar REF1 and DELTA; (**b**) Mortar REF2 and HP.

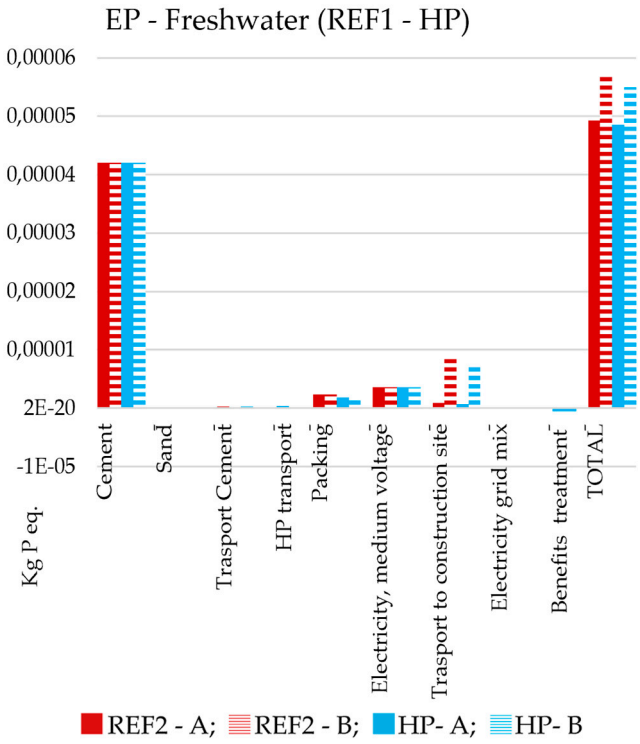
4. Eutrophication potential, fraction of nutrients reaching freshwater and compartment (EP-freshwater)

The comparison of eutrophication potential, fraction of nutrients reaching freshwater and compartment (EP-freshwater), in both scenarios (A and B) is shown in



(**a**) (**b**)

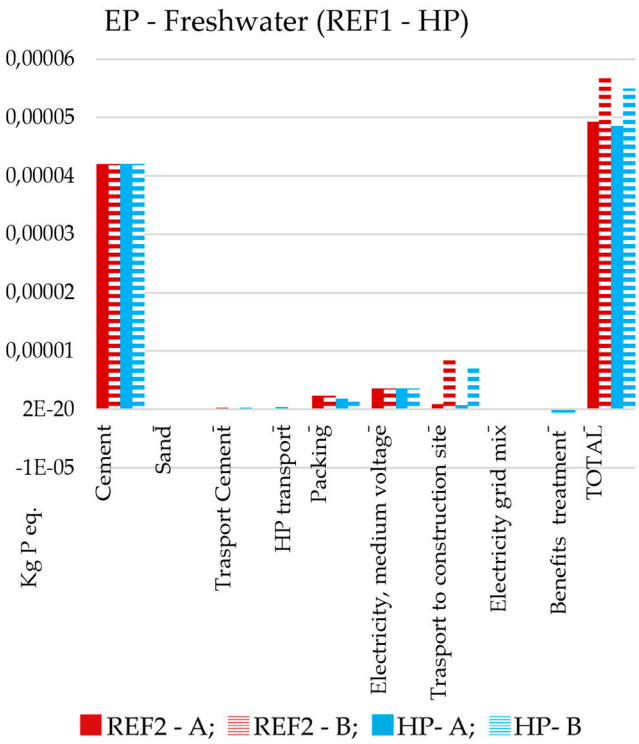
Figure S4 (a) for REF1 and DELTA mortars and in



(**a**) (**b**)

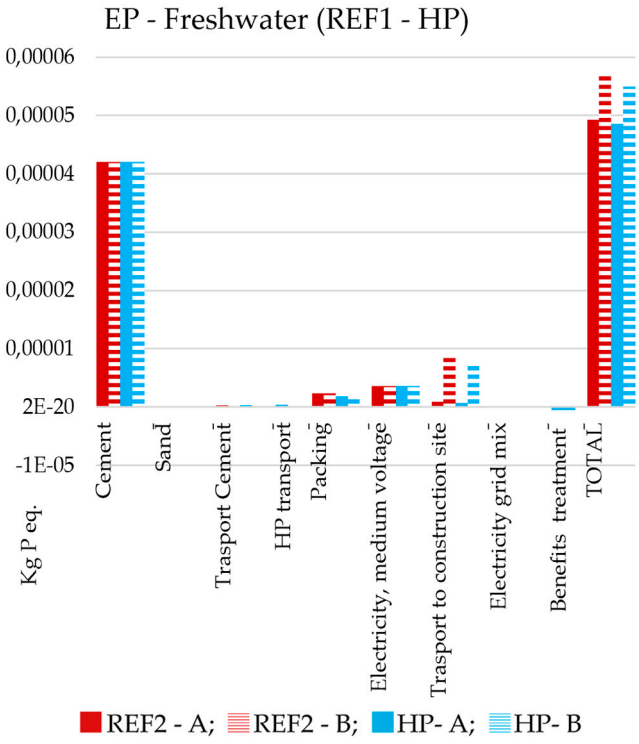
Figure S4 (b) for REF2 and HP mortars.

In terms EP-freshwater, in the same scenario, DELTA and HP mortars results slightly better performing than their reference mortars made with raw materials (respectively REF1 and REF2). EP-freshwater of DELTA mortar is reduced of 9% compared to its reference mortar REF1 in scenario A and of 14% in scenario B (



(**a**) (**b**)

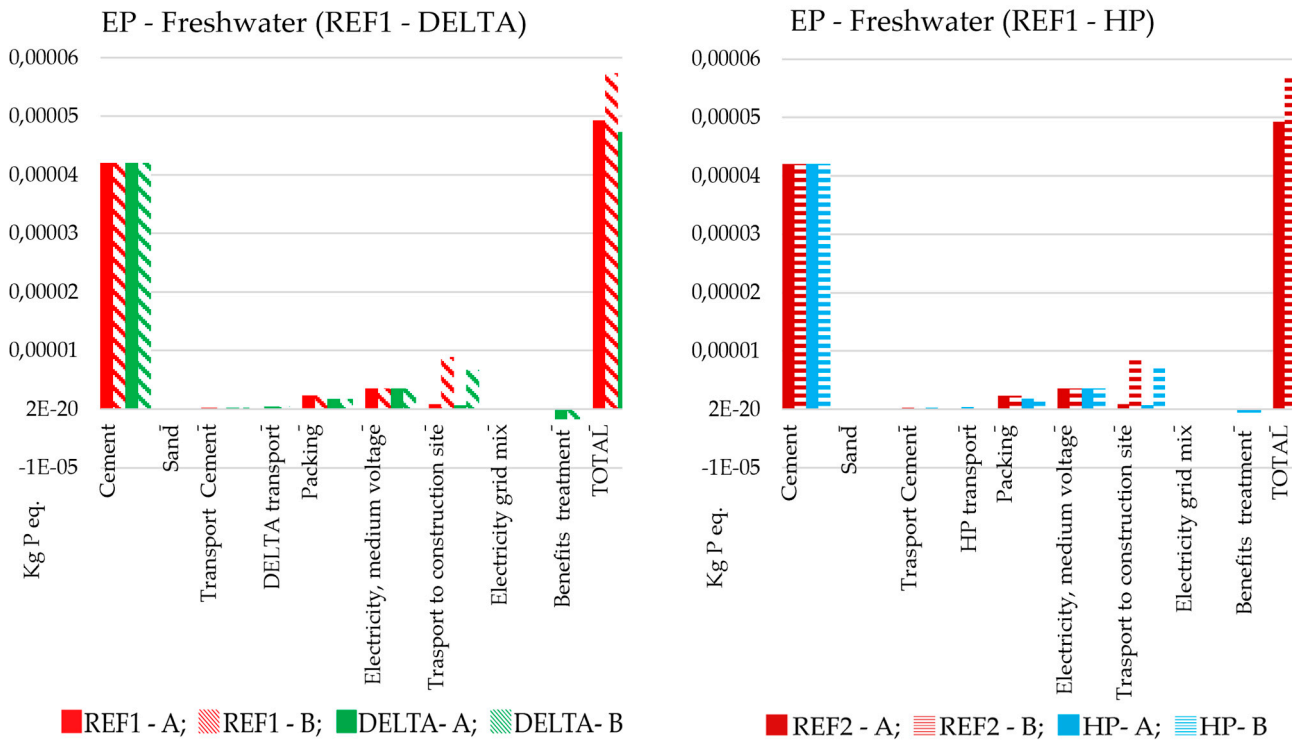
Figure S4 (a)), while HP mortar reduces EP-freshwater of 3% in scenario A and 8% in scenario B compared to mortar REF2 (



(**a**) (**b**)

Figure S4 (b)). Compared to scenario A, scenario B generates a total impact increase of 46% for REF1 and REF2 mortars, of 38% for DELTA mortar and of 37% for HP mortar.

Even in this case, the incidence of cement is the highest, especially in scenarios A (always more than 85% for every mortar mixture). In scenario B it is always more than 73%.



(**a**) (**b**)

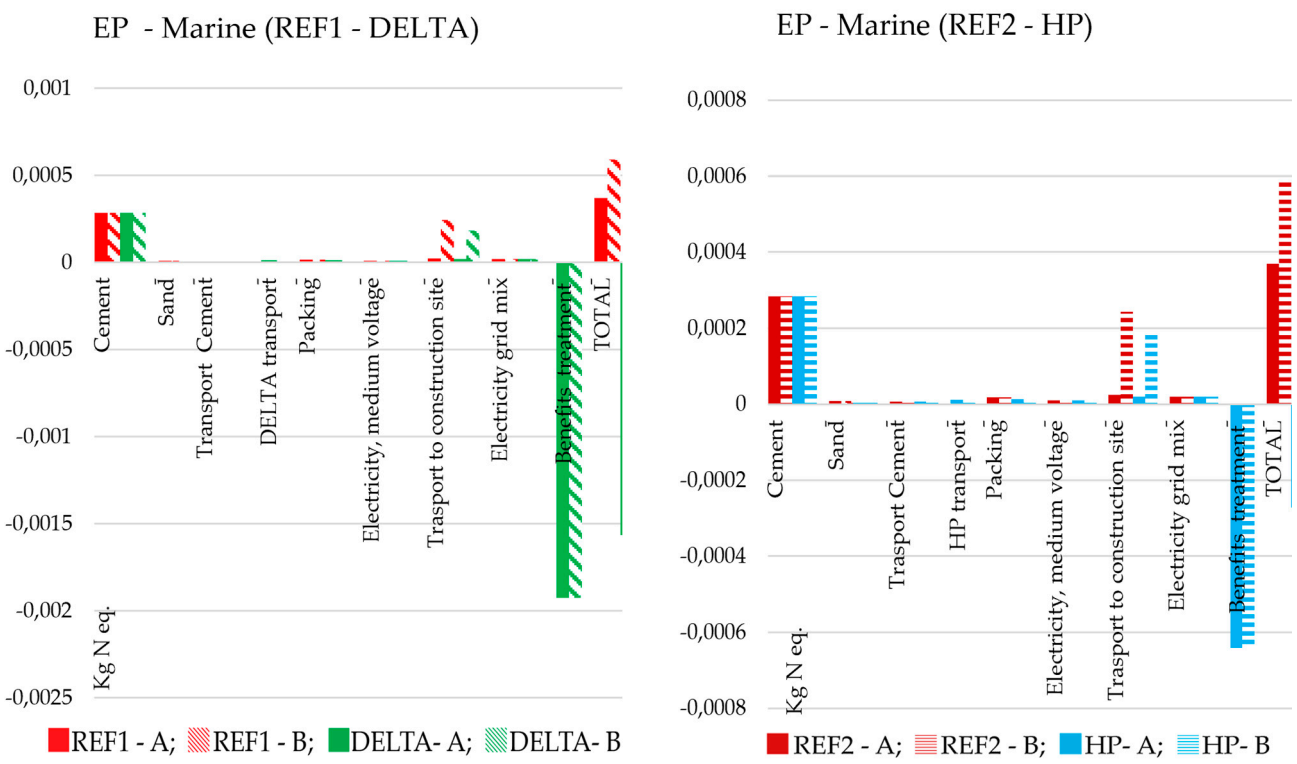
Figure S4. Eutrophication potential, fraction of nutrients reaching freshwater and compartment (EP-freshwarter) of: (**a**) Mortar REF1 and DELTA; (**b**) Mortar REF2 and HP.

5. Eutrophication potential, fraction of nutrients reaching marine and compartment (EP-marine)

The comparison of eutrophication potential fraction of nutrients reaching marine and compartment (EP-marine) in both scenarios (A and B) is shown in Figure S5 (a) for REF1 and DELTA mortars, and in Figure S5 (b) for REF2 and HP mortars.

In terms of EP-marine, DELTA and HP mortars have a significantly higher performance than their reference mortars made with raw materials (respectively REF1 and REF2), due to the high incidence of benefits link to the non-occurrence of landfill disposal and waste treatment. EP-marine of DELTA mortar results reduced of 523% compared to its reference REF1 mortar in scenario A and of 338% in scenario B (Figure S5 (a)). In addition, HP mortar reduces EP-marine of 174% in scenario A and of 117% in scenario B compared to REF2 mortar (Figure S5 (b)).

Compared to scenario A, scenario B generates ad increase in the production of EP-marine of 59% for REF1 and REF2 mortars, of 11% for DELTA mortar and of 64% for HP mortar.

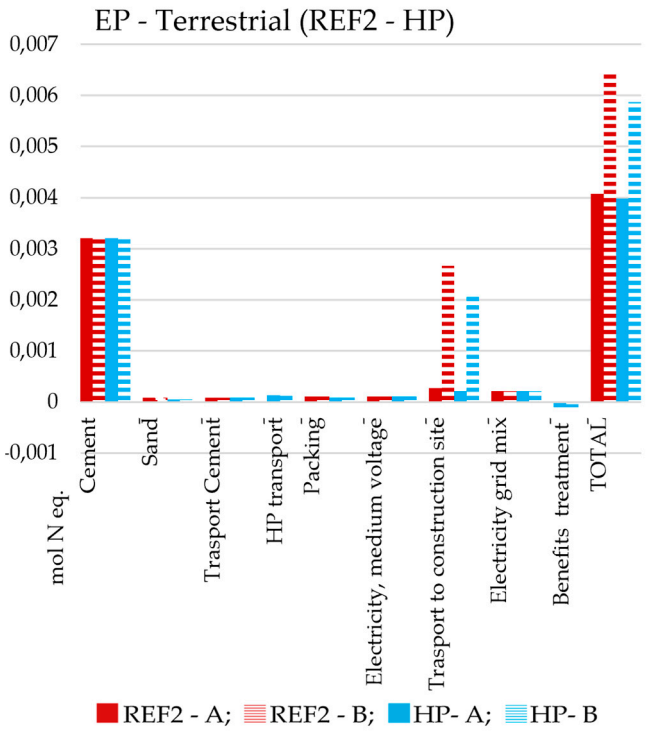


(**a**) (**b**)

Figure S5. Eutrophication potential, fraction of nutrients reaching marine and compartment (EP-marine) of: (**a**) Mortar REF1 and DELTA; (**b**) Mortar REF2 and HP.

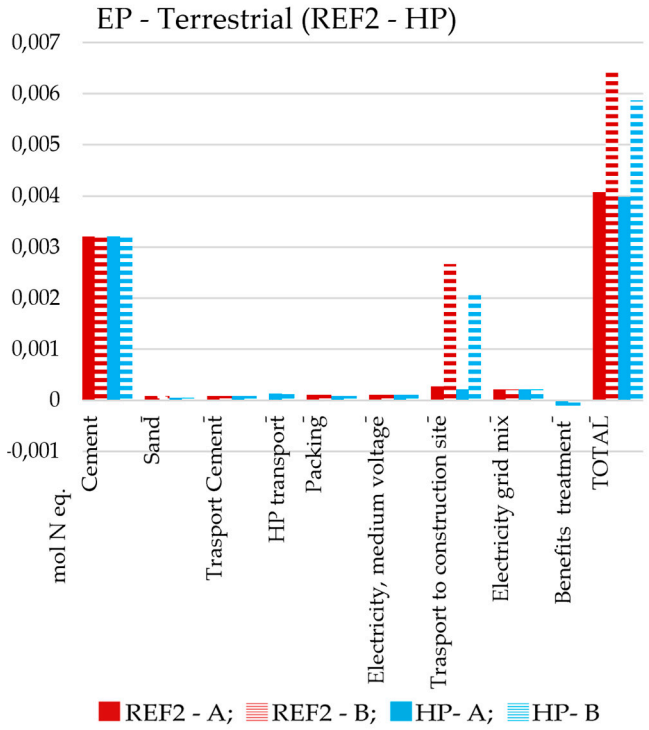
6. Eutrophication potential, Accumulated Exceedance (EP-terrestrial)

The comparison of Eutrophication potential Accumulated Exceedance (EP-terrestrial) in both scenarios (A and B) is shown in



(**a**) (**b**)

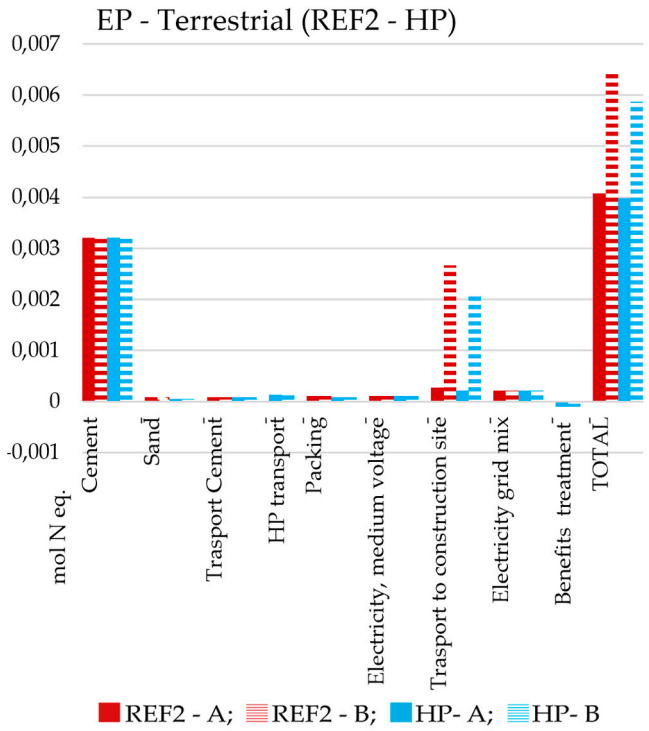
Figure S6 (a) for REF1 and DELTA mortars and in



(**a**) (**b**)

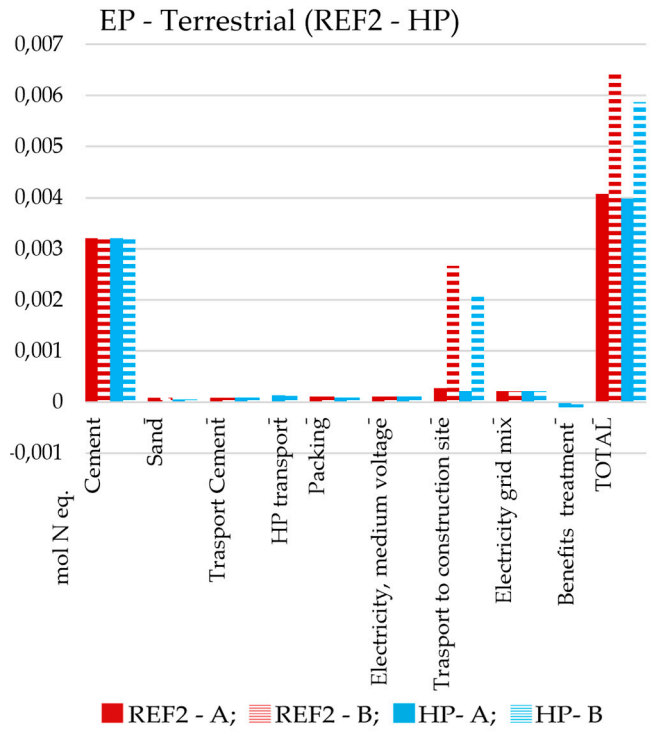
Figure S6 (b) for REF2 and HP mortars.

DELTA and HP mortars result always slightly better performing than their reference mortars made with raw materials (respectively REF1 and REF2). EP-terrestrial of DELTA mortar is 10% lower than its reference REF1 mortar in scenario A, and 16% lower in scenario B (



(**a**) (**b**)

Figure S6 (a)), while HP mortar reduces EP-terrestrial of 2% in scenario A and 9% in scenario B compared to REF2 mortar (

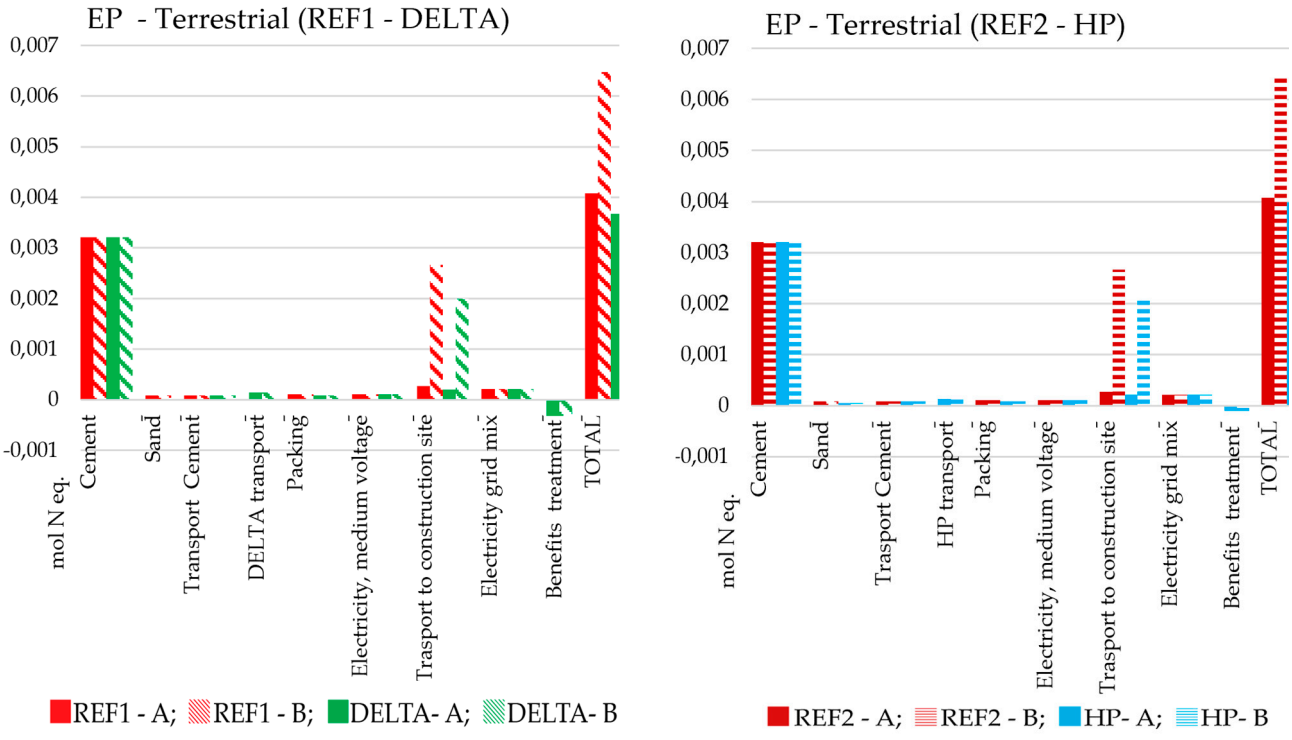


(**a**) (**b**)

Figure S6 (b)).

Compared to scenario A, scenario B generates an increase in EP-terrestrial of 59% for REF1 and REF2 mortars, of 49% for DELTA mortar and of 48% for HP mortar.

Even in this case the incidence of cement is significant, especially in scenarios A, when it is always more than 79% for every mortar mixture (but also in scenarios B it provides more than the 50% of the total impact). The incidence of transports of dry mortar from factory to construction site (module A4) is relevant too, reaching more than 36% of the total impact in scenarios B.



(**a**) (**b**)

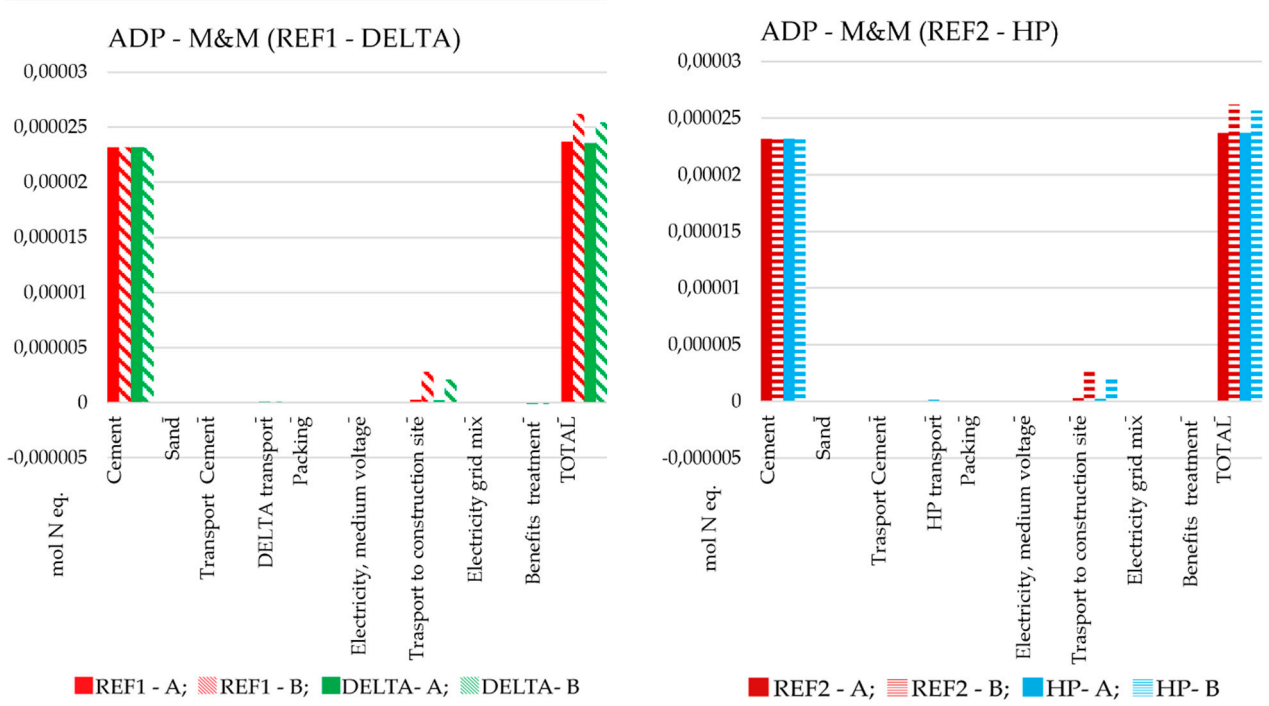
Figure S6. Eutrophication potential, Accumulated Exceedance (EP-terrestrial) of: (**a**) Mortar REF1 and DELTA; (**b**) Mortar REF2 and HP.

7. Abiotic depletion potential for non-fossil resources (ADP-Mineral & Metals)

The comparison of Abiotic depletion potential for non-fossil resources (ADP-Mineral & Metals) in both scenarios (A and B) is shown in Figure S7 (a) for REF1 and DELTA mortars and in Figure S7 (b) for REF2 and HP mortars.

Since the total ADP-Mineral & Metals impact is mostly related to cement production, and considering that cement is present in all mixtures in the same quantity, the performance of all the mixtures is practically the same: variations are below 3% both for DELTA (Figure S7 (a)) and HP (Figure S7 (b)) mortars.

Considering that transport phase has a very low influence on this impact category, scenario B generates only a slight impact increase (until 11%), while cement production is the dominant phase (98% of the impacts in A scenarios and 88%-91% in B scenarios).

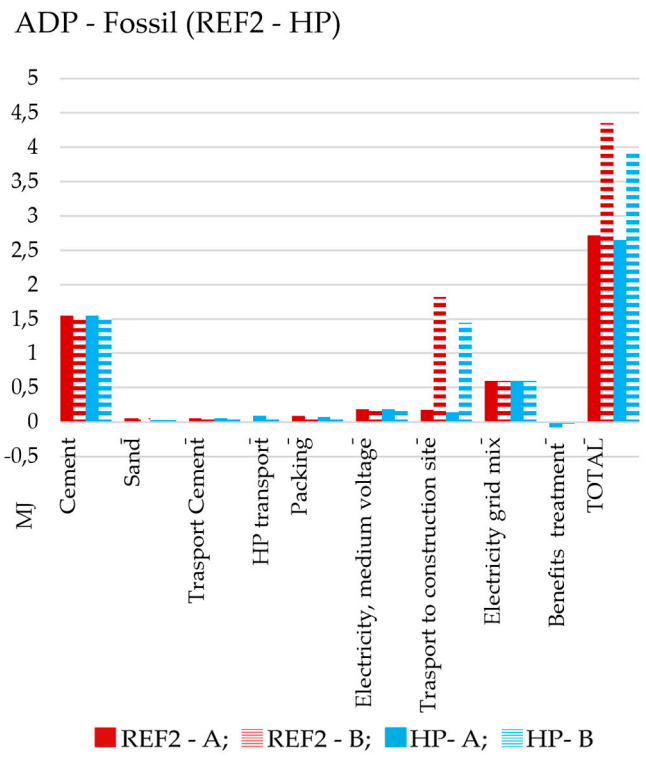


(**a**) (**b**)

Figure S7. Abiotic depletion potential for non-fossil resources (ADP-Mineral & Metals) of: (**a**) Mortar REF1 and DELTA; (**b**) Mortar REF2 and HP.

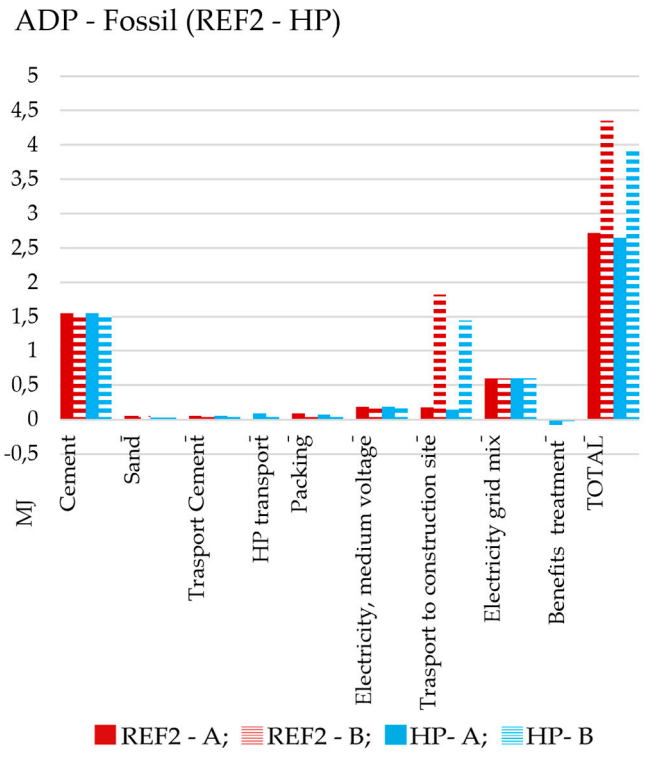
8. Abiotic depletion for fossil resourced potential (ADP-fossil)

The comparison of Abiotic depletion for fossil resourced potential (ADP-fossil) in both scenarios (A and B) is shown in



(**a**) (**b**)

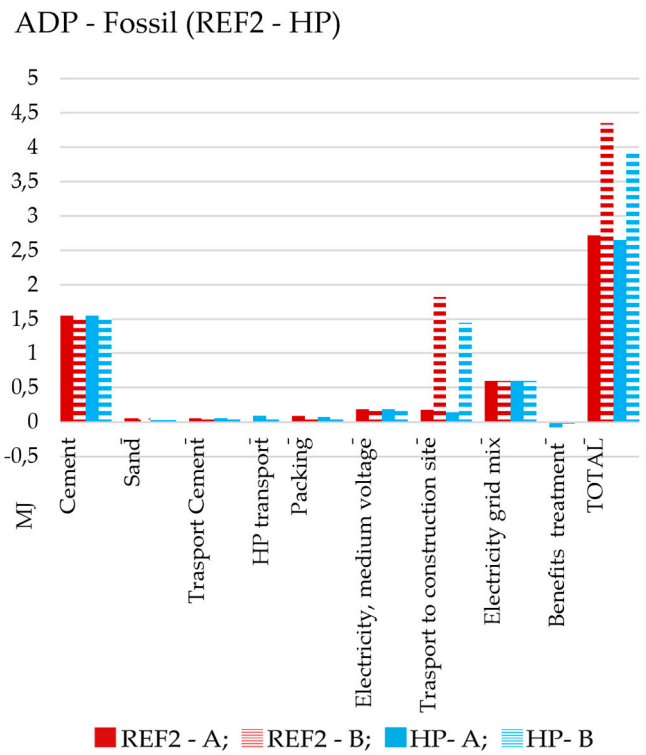
Figure S8 (a) for REF1 and DELTA mortars, and in



(**a**) (**b**)

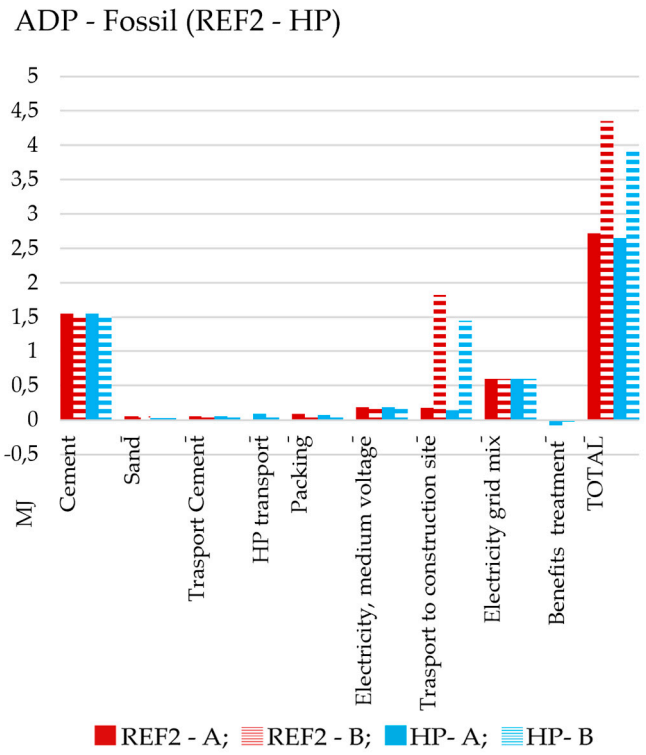
Figure S8 (b) for REF2 and HP mortars.

In terms of ADP-fossil, DELTA and HP mortars always perform better than their reference mortars made with raw materials (respectively REF1 and REF2). ADP-fossil of DELTA mortar is 11% lower compared to its reference REF1 mortar in scenario A and 16% lower in scenario B (



(**a**) (**b**)

Figure S8 (a)), while HP mortar reduces ADP-fossil of 3% in scenario A and 9% in scenario B compared to REF2 mortar (

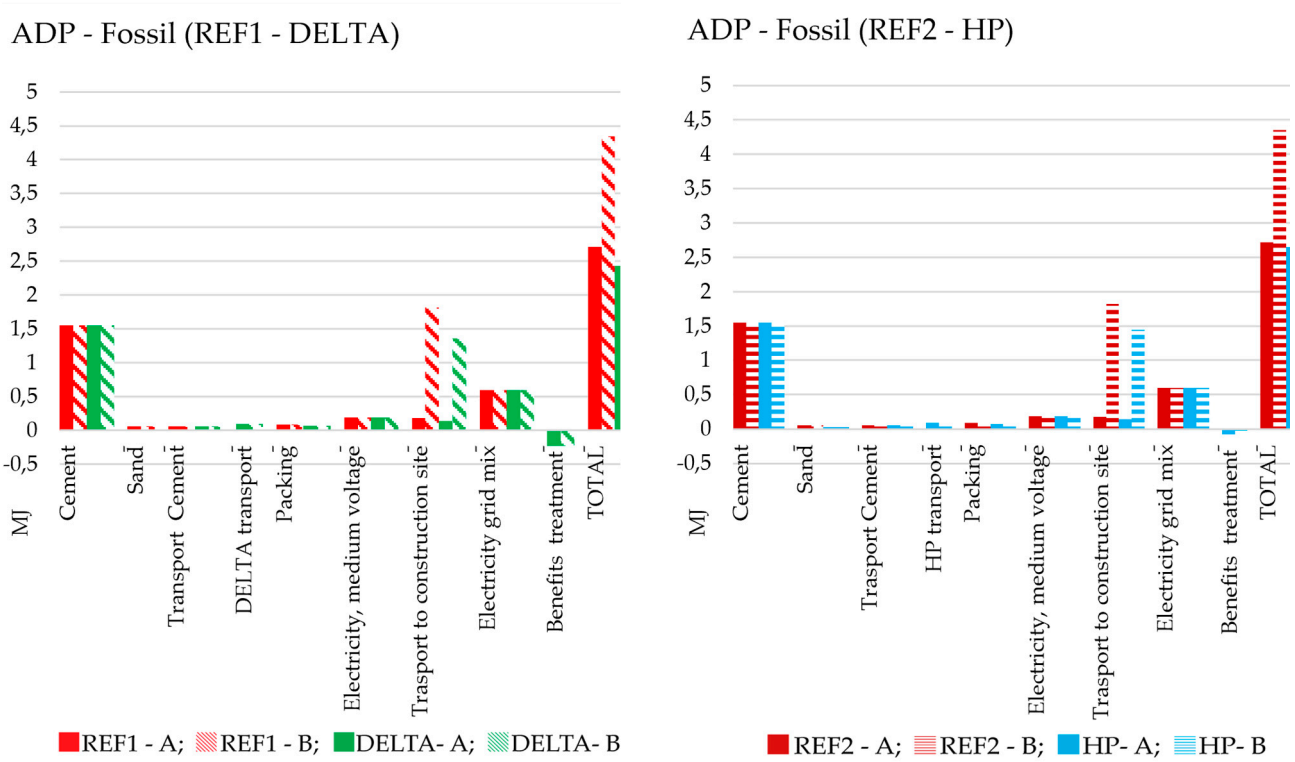


(**a**) (**b**)

Figure S8 (b)).

Compared to scenario A, scenario B generates an increase in the production of ADP-fossil of 60% for REF1 and REF2, of 51% for DELTA mortar and of 49% for HP mortar.

In scenarios A the incidence of cement is significant: 57% for REF1 and REF2, 64% for DELTA and 59% for HP. In scenarios B, also A4 transport has a non-negligible impact (between 37% and 42%):

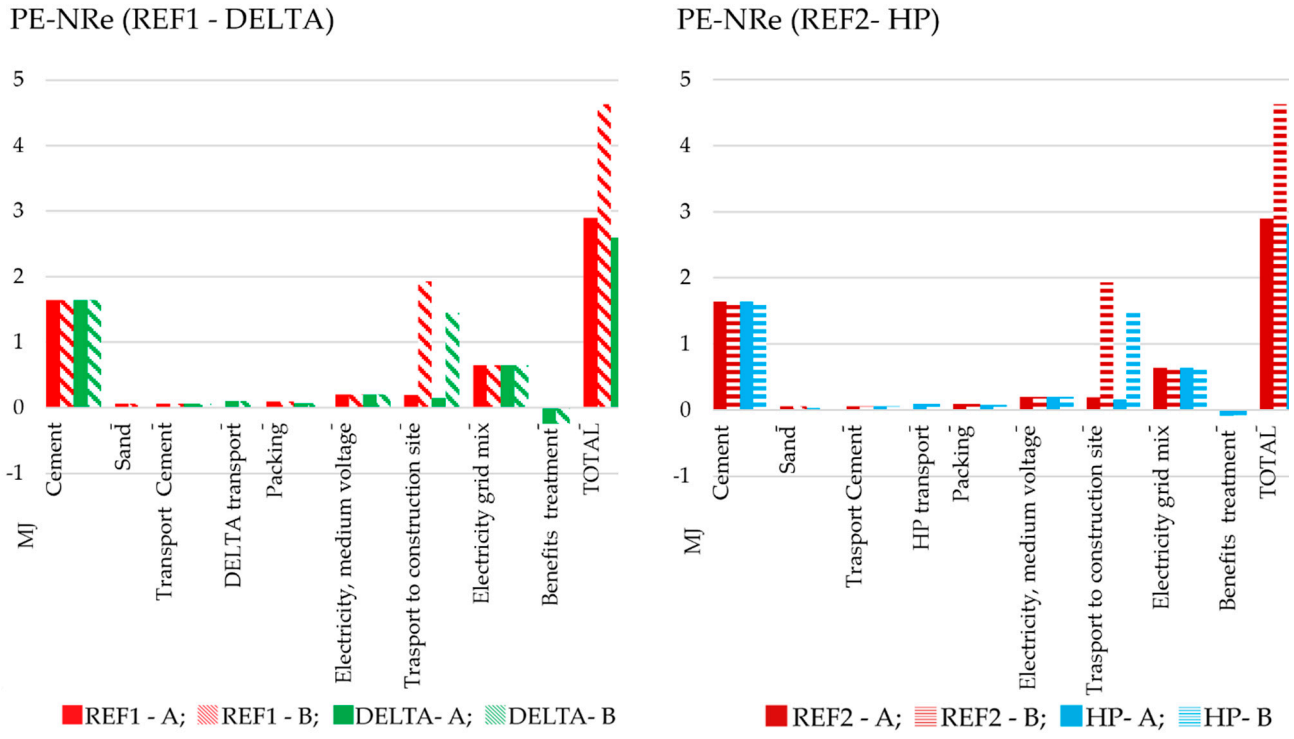


(**a**) (**b**)

Figure S8. Abiotic depletion for fossil resourced potential (ADP-fossil) of: (**a**) Mortar REF1 and DELTA; (**b**) Mortar REF2 and HP.

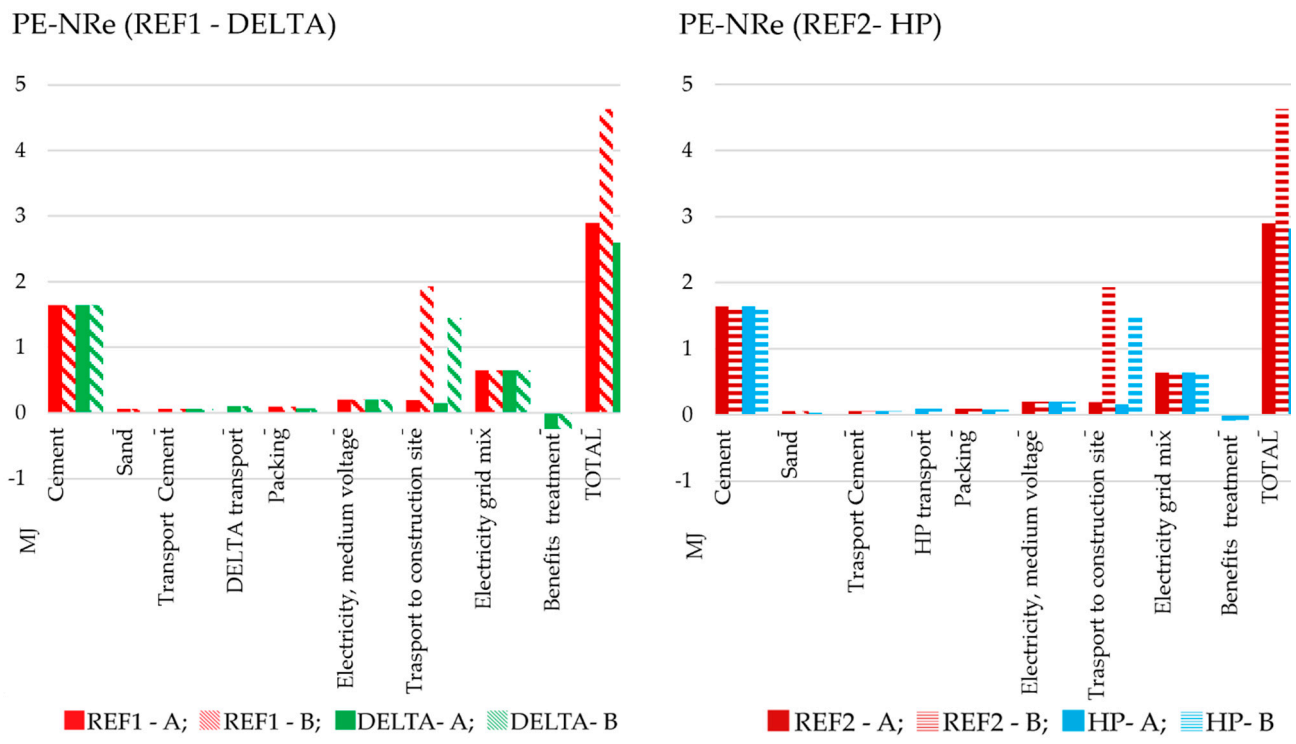
9. Use of Non-Renewable Primary Energy Resources (PE-NRe)

The comparison of Use of Non-Renewable Primary Energy Resources (PE-NRe) in both scenarios (A and B) is shown in



(**a**) (**b**)

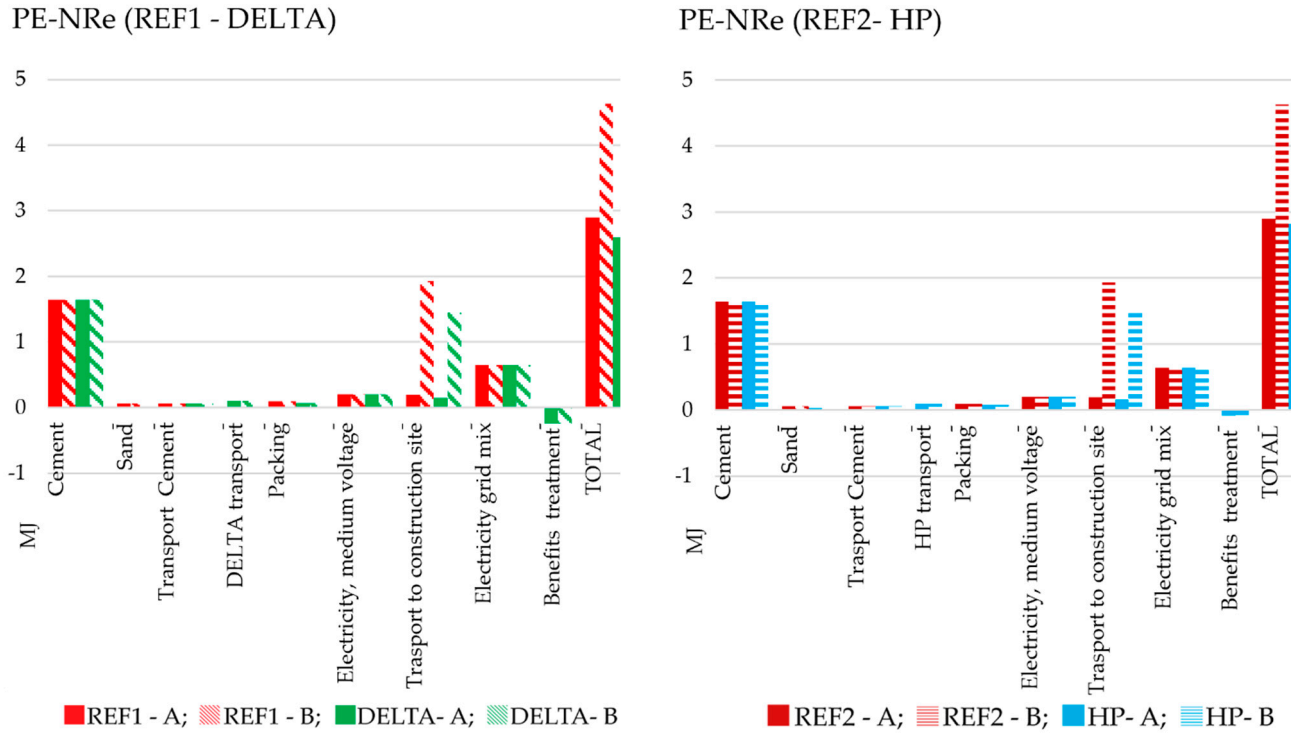
Figure S9 (a) for REF1 and DELTA mortars and in



(**a**) (**b**)

Figure S9 (b) for REF2 and HP mortars.

In terms of PE-NRe, DELTA and HP mortars perform slightly better than their reference mortars made with raw materials (respectively REF1 and REF2). PE-NRe of DELTA mortar is reduced by 11% compared to its reference mortar REF1 in scenario A and 16% in scenario B (



(**a**) (**b**)

Figure S9 (a)), while HP mortar reduces PE-NRe of 3% in scenario A and 9% in scenario B compared to mortar REF2 (

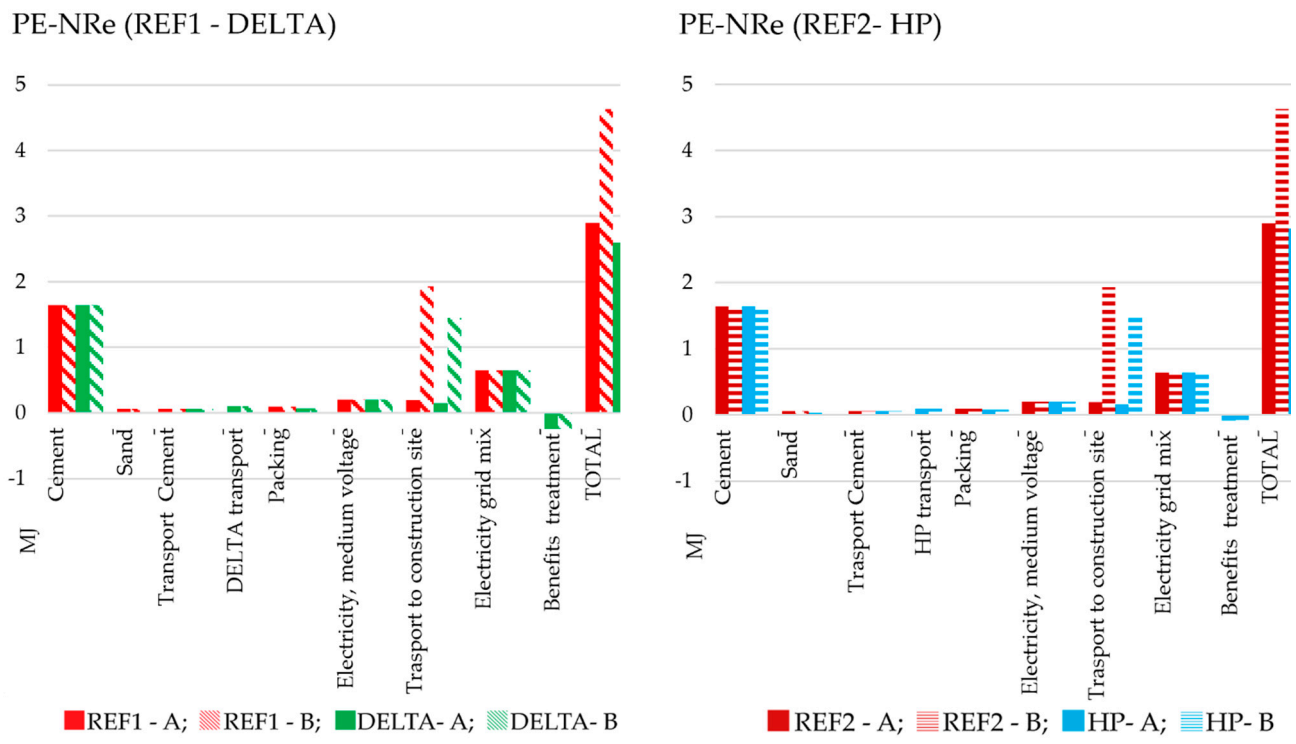


Figure S9 (b)). Compared to scenario A, scenario B generates an increase in the production of PE-NRe of 60% for REF1 and REF2 mortars, of 50% for DELTA mortar and of 49% for HP mortar.

The incidence of cement is significant especially in scenarios A: equal to 57% for REF1 and REF2; to 64% for DELTA and to 58% for HP. In scenarios B A4 transports are responsible of more than 40% of the total impact.

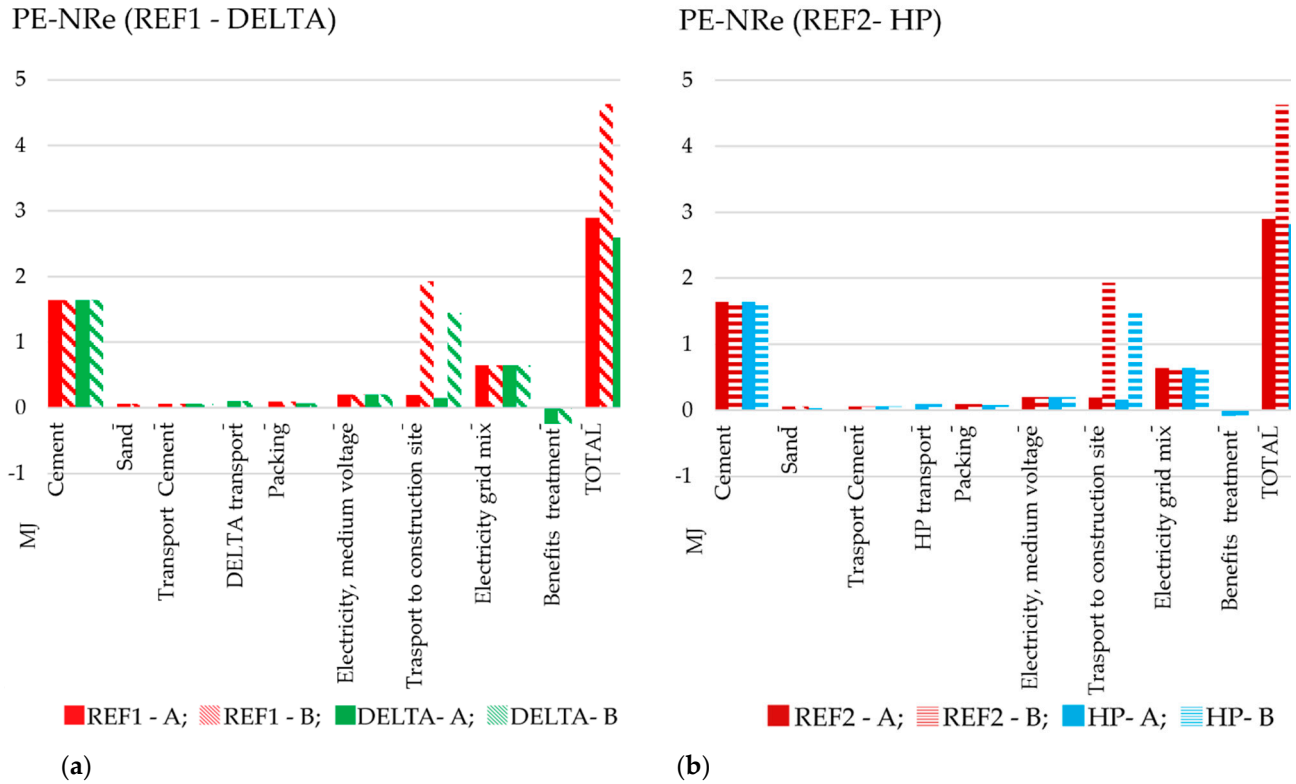


Figure S9. of Non-Renewable Primary Energy Resources (PE-NRe) of: (**a**) Mortar REF1 and DELTA; (**b**) Mortar REF2 and HP.

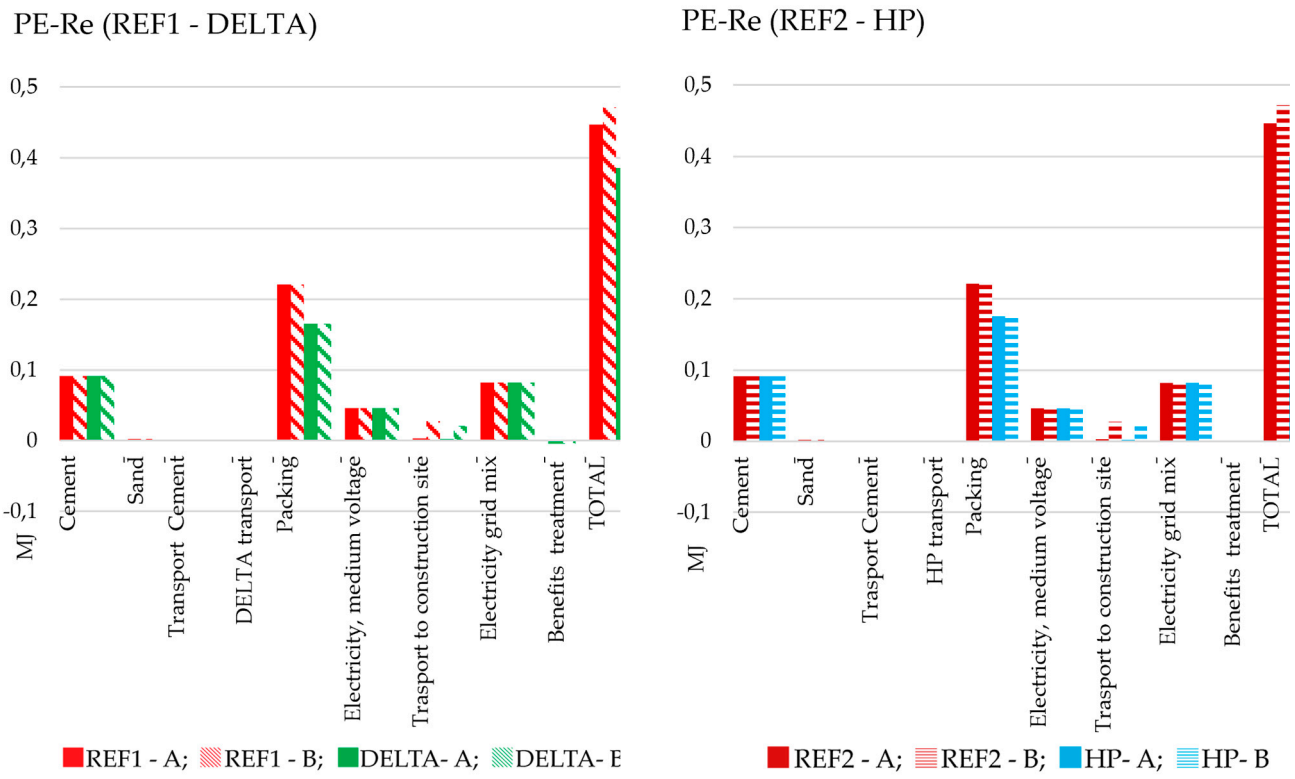
10. Use of Renewable Primary Energy Resources (PE-Re)

The comparison of Use of Renewable Primary Energy Resources (PE-Re) in both scenarios (A and B) is shown in **Error! Reference source not found.** (a) for REF1 and DELTA mortars and in **Error! Reference source not found.** (b) for REF2 and HP mortars.

In terms of PE-Re, DELTA and HP mortars perform slightly better than their reference mortars made with raw materials (respectively REF1 and REF2). DELTA mortar reduces by 14% the impact of its reference mortar REF1, both in scenarios A and B (**Error! Reference source not found.** (a)), while HP by 11% in both scenarios.

Compared to scenario A, scenario B generates an increase in PE-Re of 6% for REF1 and REF2 mortar and of 5% for DELTA and HP mortars.

For this category, packing is the most impacting phase, with a contribution on total impacts between 41% and 49% for all mixtures and scenarios.



(**a**) (**b**)

Figure S10. Use of Renewable Primary Energy Resources (PE-Re) of: (**a**) Mortar REF1 and DELTA; (**b**) Mortar REF2 and HP.