Supplementary Information

Life Cycle Assessment of wheat straw pyrolysis with volatiles fraction chemical looping combustion

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**Table S1**. Environmental Impact Indicators [13].

|  |  |  |
| --- | --- | --- |
| **Environmental Impact Indicator** | **Abbreviation** | **Unit** |
| Climate Change | GWP | kg CO2 eq. |
| Ozone depletion | ODP | kg CFC-11 eq. |
| Respiratory inorganics | RI | Disease incidences |
| Ionising radiation - human health | IR | kBq U235 eq. |
| Photochemical ozone formation - human health | POF | kg NMVOC eq. |
| Acidification terrestrial and freshwater | AC | Mole of H+ eq. |
| Eutrophication terrestrial | EUT | Mole of N eq. |
| Eutrophication freshwater | EUF | kg P eq. |
| Eutrophication marine | EUM | kg N eq. |
| Cancer human health effects | HTC | CTUh |
| Non-cancer human health effects | HTNC | CTUh |
| Ecotoxicity freshwater | ECFW | CTUe |
| Land Use | LU | Pt |
| Water scarcity | WU | m³ world equiv. |
| Resource use. mineral and metals | RDM | kg Sb eq. |
| Resource use. energy carrier | RU | MJ |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Wheat Straw production** | **CO2 biochar secuestration** | **Syngas combustion** | **Bio-oil combustion** | **CH4 thermal energy equivalence** | **TOTAL** |
| **GWP** | 1,65E-01 | -8,22E-01 | 9,55E-01 | 1,62E-01 | -6,34E-01 | -1,76E-01 |
| **ODP** | 2,44E-13 | 0,00E+00 | 1,16E-11 | 1,50E-12 | -1,97E-14 | 1,33E-11 |
| **RI** | 1,09E-08 | 0,00E+00 | 1,32E-08 | 2,25E-09 | -4,40E-09 | 2,19E-08 |
| **IR** | 4,68E-03 | 0,00E+00 | 1,78E-04 | 2,32E-05 | -4,62E-04 | 4,42E-03 |
| **POF** | 1,91E-04 | 0,00E+00 | 8,07E-03 | 1,38E-03 | -5,70E-04 | 9,07E-03 |
| **AC** | 1,22E-03 | 0,00E+00 | 5,98E-03 | 1,02E-03 | -4,57E-04 | 7,77E-03 |
| **EUT** | 5,49E-03 | 0,00E+00 | 3,44E-02 | 5,88E-03 | -2,06E-03 | 4,37E-02 |
| **EUF** | 4,25E-05 | 0,00E+00 | 7,73E-09 | 1,01E-09 | -2,29E-08 | 4,25E-05 |
| **EUM** | 5,78E-03 | 0,00E+00 | 3,14E-03 | 5,37E-04 | -1,86E-04 | 9,27E-03 |
| **HTC** | 7,83E-10 | 0,00E+00 | 3,55E-11 | 4,61E-12 | -5,90E-11 | 7,64E-10 |
| **HTNC** | 3,73E-08 | 0,00E+00 | 1,55E-10 | 2,01E-11 | -1,12E-09 | 3,63E-08 |
| **ECFW** | 1,06E+00 | 0,00E+00 | 1,54E-02 | 2,01E-03 | -1,78E-01 | 8,98E-01 |
| **LU** | 8,70E+01 | 0,00E+00 | 1,98E-02 | 2,58E-03 | -1,88E-02 | 8,70E+01 |
| **RDM** | 1,20E-08 | 0,00E+00 | 6,76E-08 | 8,80E-09 | -7,60E-09 | 8,08E-08 |
| **WU** | 1,74E+01 | 0,00E+00 | 1,48E-01 | 1,93E-02 | -1,69E-03 | 1,76E+01 |
| **RU** | 1,09E+00 | 0,00E+00 | 4,99E-02 | 6,49E-03 | -1,02E+01 | -9,01E+00 |

**Table S2-** Numerical values of the EIIs for the processes of the Case I.

**Table S3-** Numerical values of the EIIs for the processes of the case II.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Wheat Straw production** | **CO2 biochar secuestration** | **Syngas CLC combustion** | **Bio-oil combustion** | **CH4 thermal energy equivalence** | **CO2 transport and injection** | **TOTAL** |
| **GWP** | 1,65E-01 | -8,22E-01 | 4,11E-03 | 1,62E-01 | -6,03E-01 | -9,42E-01 | -2,04E+00 |
| **ODP** | 2,44E-13 | 0,00E+00 | 1,01E-11 | 1,50E-12 | -1,87E-14 | 1,72E-16 | 1,18E-11 |
| **RI** | 1,09E-08 | 0,00E+00 | 2,72E-10 | 2,25E-09 | -4,18E-09 | 4,13E-11 | 9,24E-09 |
| **IR** | 4,68E-03 | 0,00E+00 | 1,58E-04 | 2,32E-05 | -4,39E-04 | 4,27E-06 | 4,42E-03 |
| **POF** | 1,91E-04 | 0,00E+00 | 2,06E-05 | 1,38E-03 | -5,42E-04 | 5,36E-06 | 1,06E-03 |
| **AC** | 1,22E-03 | 0,00E+00 | 2,34E-05 | 1,02E-03 | -4,34E-04 | 4,29E-06 | 1,84E-03 |
| **EUT** | 5,49E-03 | 0,00E+00 | 8,03E-05 | 5,88E-03 | -1,95E-03 | 1,93E-05 | 9,52E-03 |
| **EUF** | 4,25E-05 | 0,00E+00 | 6,80E-09 | 1,01E-09 | -2,18E-08 | 2,12E-10 | 4,25E-05 |
| **EUM** | 5,78E-03 | 0,00E+00 | 7,42E-06 | 5,37E-04 | -1,77E-04 | 1,74E-06 | 6,15E-03 |
| **HTC** | 7,83E-10 | 0,00E+00 | 3,10E-11 | 4,61E-12 | -5,61E-11 | 5,54E-13 | 7,63E-10 |
| **HTNC** | 3,73E-08 | 0,00E+00 | 1,36E-10 | 2,01E-11 | -1,07E-09 | 1,05E-11 | 3,64E-08 |
| **ECFW** | 1,06E+00 | 0,00E+00 | 1,36E-02 | 2,01E-03 | -1,69E-01 | 1,67E-03 | 9,07E-01 |
| **LU** | 8,70E+01 | 0,00E+00 | 1,74E-02 | 2,58E-03 | -1,79E-02 | 1,72E-04 | 8,70E+01 |
| **RDM** | 1,20E-08 | 0,00E+00 | 6,54E-08 | 8,80E-09 | -7,23E-09 | 7,11E-11 | 7,90E-08 |
| **WU** | 1,74E+01 | 0,00E+00 | 1,30E-01 | 1,93E-02 | -1,61E-03 | 8,06E-04 | 1,75E+01 |
| **RU** | 1,09E+00 | 0,00E+00 | 4,48E-02 | 6,49E-03 | -9,66E+00 | 9,55E-02 | -8,43E+00 |

**Table S4-** Numerical values of the EIIs for the processes of the case III.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Wheat Straw production** | **CO2 biochar secuestration** | **Volatiles CLC combustion** | **CH4 thermal energy equivalence** | **CO2 transport and injection** | **TOTAL** |
| **GWP** | 1,65E-01 | -8,22E-01 | 4,64E-03 | -6,00E-01 | -1,09E+00 | -2,34E+00 |
| **ODP** | 2,44E-13 | 0,00E+00 | 1,14E-11 | -1,86E-14 | 1,99E-16 | 1,16E-11 |
| **RI** | 1,09E-08 | 0,00E+00 | 3,06E-10 | -4,15E-09 | 4,78E-11 | 7,06E-09 |
| **IR** | 4,68E-03 | 0,00E+00 | 1,78E-04 | -4,36E-04 | 4,95E-06 | 4,42E-03 |
| **POF** | 1,91E-04 | 0,00E+00 | 2,29E-05 | -5,39E-04 | 6,20E-06 | -3,19E-04 |
| **AC** | 1,22E-03 | 0,00E+00 | 2,62E-05 | -4,32E-04 | 4,97E-06 | 8,22E-04 |
| **EUT** | 5,49E-03 | 0,00E+00 | 8,92E-05 | -1,94E-03 | 2,24E-05 | 3,66E-03 |
| **EUF** | 4,25E-05 | 0,00E+00 | 7,68E-09 | -2,16E-08 | 2,45E-10 | 4,25E-05 |
| **EUM** | 5,78E-03 | 0,00E+00 | 8,24E-06 | -1,76E-04 | 2,02E-06 | 5,62E-03 |
| **HTC** | 7,83E-10 | 0,00E+00 | 3,50E-11 | -5,58E-11 | 6,42E-13 | 7,63E-10 |
| **HTNC** | 3,73E-08 | 0,00E+00 | 1,53E-10 | -1,06E-09 | 1,22E-11 | 3,64E-08 |
| **ECFW** | 1,06E+00 | 0,00E+00 | 1,54E-02 | -1,68E-01 | 1,93E-03 | 9,08E-01 |
| **LU** | 8,70E+01 | 0,00E+00 | 1,97E-02 | -1,78E-02 | 2,00E-04 | 8,70E+01 |
| **RDM** | 1,20E-08 | 0,00E+00 | 7,37E-08 | -7,19E-09 | 8,24E-11 | 7,85E-08 |
| **WU** | 1,74E+01 | 0,00E+00 | 1,46E-01 | -1,60E-03 | 9,33E-04 | 1,75E+01 |
| **RU** | 1,09E+00 | 0,00E+00 | 5,05E-02 | -9,60E+00 | 1,11E-01 | -8,35E+00 |