**SUPPLEMENTARY DATA**
Baillet, V., Pauthier, B., Payen, A., Naviaux, P., Symoneaux, R., Chassaing, T., & Renaud-Gentié, C. (2025). Context-Specific Life Cycle Assessment of Active Spring Frost Protection Methods in Viticulture in the Loire Valley and Champagne French Regions. *OENO One*, *59*(1).
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# SUPPLEMENTARY DATA

**Table S1.** LCA uncertainty analysis with Impact world + methodology. FU1: to protect 1 ha of vine plot during 1 hour of frost. FU2: to protect 1 ha of vine with 1 fold and unfold operation. The table includes the mean, median, standard deviation, coefficient of variation (in absolute value) and the standard error for each environmental indicator. The uncertainty analysis was performed with SimaPro software using Monte Carlo analysis with 1000 iterations and a 95 % confidence interval. AC1-C: antifrost candles, champagne region, petrol as raw material. AC2-C: antifrost candles, champagne region, palm oil as raw material. AC1-V: antifrost candles, Loire Valley region, petrol as raw material. FWM1-C: wind machine, Champagne region, fixed machine, gas fuel, with small heaters. FWM2-C: wind machine, Champagne region, fixed machine, gas fuel, without small heaters. FWM3-C: wind machine, Champagne region, fixed machine, gas fuel, with burner. MWM1-C: wind machine, Champagne region, mobile machine, diesel fuel, with a small heater. MWM2-C: wind machine, Champagne region, mobile machine, diesel fuel, with burner. FWM1-V: wind machine, Loire Valley region, fixed machine, diesel fuel, with small heaters. FWM2-V: wind machine, Loire Valley region, fixed, gas fuel, with small heaters. FWM3-V: wind machine, Loire Valley region, fixed, diesel fuel, without small heaters. FWM4-V: wind machine, Loire Valley region, fixed, diesel fuel, with burner. MWM1-V: wind machine, Loire Valley region, mobile, diesel fuel, with small heater and generator. MWM2-V: wind machine, Loire Valley region, mobile, diesel fuel, with a small heater. H1-C: heater, Champagne region, fuel as an energy resource. H2-C: heater, Champagne region, wood as an energy resource. H1-V: heater, Loire Valley region, fuel as an energy resource. H2-V: heater, Loire Valley region, uses wood as an energy resource. H3-V: heater, Loire Valley region, uses peat as an energy resource. HC1-C: heating cable, Champagne region, copper cable. HC1-V: heating cable, Loire Valley region, copper cable. HC2-V: heating cable, Loire Valley region, radiative cable with diode. S1-C: sprinkler, Champagne region, 50 $m^3$ of direct water consumption. S1-V: sprinkler, Loire Valley region, 35 $m^3$ of direct water consumption. WC1-V: winter cover, Loire Valley region, non-woven polypropylene cover

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| ASFPM | Impact category | Unit | Average | Median | Standard deviation | Coefficient of variation | 2.50 % | 97.50 % | Standard error of the mean |
|---|---|---|---|---|---|---|---|---|---|
| **AC1-C[1]** | Climate change, short term | kg $CO_2$ eq | 1.60E+03 | 1.59E+03 | 9.64E+01 | 6.04E+00 | 1.42E+03 | 1.80E+03 | 3.05E+00 |
| **AC1-C[1]** | Fossil and nuclear energy use | MJ deprived | 2.09E+04 | 2.07E+04 | 2.93E+03 | 1.40E+01 | 1.59E+04 | 2.74E+04 | 9.25E+01 |
| **AC1-C[1]** | Human toxicity cancer | CTUh | 5.70E-04 | 5.01E-04 | 2.81E-04 | 4.92E+01 | 2.36E-04 | 1.29E-03 | 8.87E-06 |
| **AC1-C[1]** | Land occupation, biodiversity | $m^2$/yr arable | 1.45E+01 | 1.39E+01 | 3.34E+00 | 2.31E+01 | 9.54E+00 | 2.27E+01 | 1.06E-01 |
| **AC1-C[1]** | Mineral resources use | kg deprived | 2.53E+01 | 2.43E+01 | 7.10E+00 | 2.81E+01 | 1.53E+01 | 4.25E+01 | 2.25E-01 |
| **AC1-C[1]** | Terrestrial acidification | kg $SO_2$ eq | 7.44E-03 | 6.80E-03 | 2.85E-03 | 3.83E+01 | 5.03E-03 | 1.38E-02 | 9.02E-05 |
| **AC1-C[1]** | Water scarcity | $m^3$ world eq | 2.66E+02 | 5.72E+02 | 3.97E+03 | 1.49E+03 | –7.95E+03 | 7.51E+03 | 1.26E+02 |
| **AC1-V[1]** | Climate change. short term | kg $CO_2$ eq | 8.31E+02 | 8.30E+02 | 5.17E+01 | 6.22E+00 | 7.36E+02 | 9.46E+02 | 1.63E+00 |
| **AC1-V[1]** | Fossil and nuclear energy use | MJ deprived | 1.10E+04 | 1.09E+04 | 1.62E+03 | 1.47E+01 | 8.17E+03 | 1.46E+04 | 5.12E+01 |
| **AC1-V[1]** | Human toxicity cancer | CTUh | 2.91E-04 | 2.63E-04 | 1.28E-04 | 4.38E+01 | 1.17E-04 | 6.33E-04 | 4.04E-06 |
| **AC1-V[1]** | Land occupation. biodiversity | $m^2$/yr arable | 9.13E+00 | 8.72E+00 | 2.18E+00 | 2.39E+01 | 5.75E+00 | 1.46E+01 | 6.90E-02 |
| **AC1-V[1]** | Mineral resources use | kg deprived | 1.29E+01 | 1.24E+01 | 3.44E+00 | 2.67E+01 | 7.91E+00 | 2.09E+01 | 1.09E-01 |
| **AC1-V[1]** | Terrestrial acidification | kg $SO_2$ eq | 3.86E-03 | 3.51E-03 | 1.41E-03 | 3.65E+01 | 2.62E-03 | 7.13E-03 | 4.46E-05 |
| **AC1-V[1]** | Water scarcity | $m^3$ world eq | 8.53E+01 | 2.26E+02 | 2.18E+03 | 2.56E+03 | -4.70E+03 | 3.79E+03 | 6.90E+01 |
| **AC2-C[1]** | Climate change, short term | kg $CO_2$ eq | 1.98E+03 | 1.83E+03 | 9.91E+02 | 5.00E+01 | 5.31E+02 | 4.48E+03 | 3.13E+01 |
| **AC2-C[1]** | Fossil and nuclear energy use | MJ deprived | 9.56E+03 | 9.13E+03 | 2.50E+03 | 2.61E+01 | 6.16E+03 | 1.53E+04 | 7.89E+01 |
| **AC2-C[1]** | Human toxicity cancer | CTUh | 1.06E-03 | 9.68E-04 | 5.75E-04 | 5.40E+01 | 3.37E-04 | 2.38E-03 | 1.82E-05 |
| **AC2-C[1]** | Land occupation, biodiversity | $m^2$/yr arable | 1.26E+02 | 1.17E+02 | 4.42E+01 | 3.50E+01 | 6.44E+01 | 2.36E+02 | 1.40E+00 |
| **AC2-C[1]** | Mineral resources use | kg deprived | 4.28E+01 | 4.11E+01 | 1.08E+01 | 2.53E+01 | 2.57E+01 | 6.79E+01 | 3.42E-01 |

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| ASFPM | Impact category | Unit | Average | Median | Standard deviation | Coefficient of variation | 2.50 % | 97.50 % | Standard error of the mean |
|---|---|---|---|---|---|---|---|---|---|
| **AC2-C[1]** | Terrestrial acidification | kg $SO_2$ eq | 1.17E-02 | 1.13E-02 | 3.00E-03 | 2.57E+01 | 7.12E-03 | 1.86E-02 | 9.50E-05 |
| **AC2-C[1]** | Water scarcity | $m^3$ world eq | 2.19E+03 | 3.43E+03 | 1.37E+04 | 6.25E+02 | –2.91E+04 | 2.60E+04 | 4.34E+02 |
| **FWM1-C[1]** | Climate change, short term | kg $CO_2$ eq | 1.41E+02 | 1.40E+02 | 7.26E+00 | 5.16E+00 | 1.27E+02 | 1.56E+02 | 2.29E-01 |
| **FWM1-C[1]** | Fossil and nuclear energy use | MJ deprived | 2.14E+03 | 2.12E+03 | 1.43E+02 | 6.69E+00 | 1.90E+03 | 2.47E+03 | 4.53E+00 |
| **FWM1-C[1]** | Human toxicity cancer | CTUh | 3.05E-04 | 2.82E-04 | 1.25E-04 | 4.10E+01 | 1.40E-04 | 6.19E-04 | 3.95E-06 |
| **FWM1-C[1]** | Land occupation, biodiversity | $m_2$/yr arable | 3.40E+00 | 3.35E+00 | 3.10E-01 | 9.13E+00 | 2.95E+00 | 4.12E+00 | 9.80E-03 |
| **FWM1-C[1]** | Mineral resources use | kg deprived | 1.72E+01 | 1.67E+01 | 3.18E+00 | 1.85E+01 | 1.23E+01 | 2.48E+01 | 1.01E-01 |
| **FWM1-C[1]** | Terrestrial acidification | kg $SO_2$ eq | 1.09E-03 | 1.09E-03 | 7.33E-05 | 6.71E+00 | 9.61E-04 | 1.25E-03 | 2.32E-06 |
| **FWM1-C[1]** | Water scarcity | $m^3$ world eq | 1.57E+02 | 5.21E+02 | 4.43E+03 | 2.82E+03 | –9.02E+03 | 7.82E+03 | 1.40E+02 |
| **FWM1-V[1]** | Climate change, short term | kg $CO_2$ eq | 1.82E+02 | 1.80E+02 | 1.60E+01 | 8.83E+00 | 1.55E+02 | 2.17E+02 | 5.07E-01 |
| **FWM1-V[1]** | Fossil and nuclear energy use | MJ deprived | 2.11E+03 | 2.06E+03 | 2.85E+02 | 1.35E+01 | 1.64E+03 | 2.77E+03 | 9.02E+00 |
| **FWM1-V[1]** | Human toxicity cancer | CTUh | 2.44E-04 | 2.26E-04 | 9.68E-05 | 3.97E+01 | 1.05E-04 | 4.90E-04 | 3.06E-06 |
| **FWM1-V[1]** | Land occupation, biodiversity | $m^2$yr arable | 4.44E+00 | 4.38E+00 | 5.37E-01 | 1.21E+01 | 3.64E+00 | 5.69E+00 | 1.70E-02 |
| **FWM1-V[1]** | Mineral resources use | kg deprived | 1.35E+01 | 1.32E+01 | 2.47E+00 | 1.83E+01 | 9.49E+00 | 1.91E+01 | 7.81E-02 |
| **FWM1-V[1]** | Terrestrial acidification | kg $SO_2$ eq | 1.71E-03 | 1.69E-03 | 1.76E-04 | 1.03E+01 | 1.40E-03 | 2.12E-03 | 5.57E-06 |
| **FWM1-V[1]** | Water scarcity | $m^3$ world eq | 1.52E+02 | 4.33E+02 | 4.64E+03 | 3.06E+03 | –1.05E+04 | 8.22E+03 | 1.47E+02 |
| **FWM2-C[1]** | Climate change, short term | kg $CO_2$ eq | 1.14E+02 | 1.14E+02 | 6.21E+00 | 5.45E+00 | 1.03E+02 | 1.28E+02 | 1.96E-01 |
| **FWM2-C[1]** | Fossil and nuclear energy use | MJ deprived | 1.80E+03 | 1.79E+03 | 1.07E+02 | 5.93E+00 | 1.61E+03 | 2.05E+03 | 3.38E+00 |
| **FWM2-C[1]** | Human toxicity cancer | CTUh | 2.66E-04 | 2.46E-04 | 1.11E-04 | 4.16E+01 | 1.11E-04 | 5.42E-04 | 3.49E-06 |

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| ASFPM | Impact category | Unit | Average | Median | Standard deviation | Coefficient of variation | 2.50 % | 97.50 % | Standard error of the mean |
|---|---|---|---|---|---|---|---|---|---|
| **FWM2-C[1]** | Land occupation, biodiversity | $m^2$/yr arable | 1.36E+00 | 1.34E+00 | 1.77E-01 | 1.30E+01 | 1.11E+00 | 1.76E+00 | 5.59E-03 |
| **FWM2-C[1]** | Mineral resources use | kg deprived | 1.51E+01 | 1.49E+01 | 2.82E+00 | 1.86E+01 | 1.08E+01 | 2.16E+01 | 8.91E-02 |
| **FWM2-C[1]** | Terrestrial acidification | kg $SO_2$ eq | 6.38E-04 | 6.36E-04 | 3.43E-05 | 5.38E+00 | 5.73E-04 | 7.13E-04 | 1.08E-06 |
| **FWM2-C[1]** | Water scarcity | $m^3$ world eq | –2.13E+02 | 1.81E+02 | 3.37E+03 | –1.58E+03 | –8.91E+03 | 5.37E+03 | 1.07E+02 |
| **FWM2-V[1]** | Climate change, short term | kg $CO_2$ eq | 1.13E+02 | 1.13E+02 | 6.25E+00 | 5.54E+00 | 1.02E+02 | 1.28E+02 | 1.98E-01 |
| **FWM2-V[1]** | Fossil and nuclear energy use | MJ deprived | 1.64E+03 | 1.63E+03 | 1.06E+02 | 6.50E+00 | 1.46E+03 | 1.89E+03 | 3.37E+00 |
| **FWM2-V[1]** | Human toxicity cancer | CTUh | 2.27E-04 | 2.12E-04 | 9.14E-05 | 4.02E+01 | 9.63E-05 | 4.48E-04 | 2.89E-06 |
| **FWM2-V[1]** | Land occupation, biodiversity | $m^2$/yr arable | 2.62E+00 | 2.60E+00 | 2.21E-01 | 8.44E+00 | 2.28E+00 | 3.12E+00 | 7.00E-03 |
| **FWM2-V[1]** | Mineral resources use | kg deprived | 1.33E+01 | 1.29E+01 | 2.47E+00 | 1.85E+01 | 9.53E+00 | 1.94E+01 | 7.80E-02 |
| **FWM2-V[1]** | Terrestrial acidification | kg $SO_2$ eq | 8.43E-04 | 8.38E-04 | 5.50E-05 | 6.52E+00 | 7.49E-04 | 9.63E-04 | 1.74E-06 |
| **FWM2-V[1]** | Water scarcity | $m^3$ world eq | 1.18E+02 | 4.65E+02 | 3.35E+03 | 2.85E+03 | –7.46E+03 | 6.17E+03 | 1.06E+02 |
| **FWM3-C[1]** | Climate change, short term | kg $CO_2$ eq | 1.74E+02 | 1.73E+02 | 7.98E+00 | 4.60E+00 | 1.59E+02 | 1.91E+02 | 2.52E-01 |
| **FWM3-C[1]** | Fossil and nuclear energy use | MJ deprived | 2.55E+03 | 2.53E+03 | 1.76E+02 | 6.89E+00 | 2.25E+03 | 2.96E+03 | 5.55E+00 |
| **FWM3-C[1]** | Human toxicity cancer | CTUh | 3.64E-04 | 3.33E-04 | 1.55E-04 | 4.26E+01 | 1.61E-04 | 7.53E-04 | 4.91E-06 |
| **FWM3-C[1]** | Land occupation, biodiversity | $m^2$/yr arable | 3.58E+00 | 3.54E+00 | 3.76E-01 | 1.05E+01 | 3.10E+00 | 4.40E+00 | 1.19E-02 |
| **FWM3-C[1]** | Mineral resources use | kg deprived | 2.01E+01 | 1.96E+01 | 3.69E+00 | 1.84E+01 | 1.44E+01 | 2.83E+01 | 1.17E-01 |
| **FWM3-C[1]** | Terrestrial acidification | kg $SO_2$ eq | 1.22E-03 | 1.21E-03 | 8.87E-05 | 7.29E+00 | 1.07E-03 | 1.41E-03 | 2.80E-06 |
| **FWM3-C[1]** | Water scarcity | $m^3$ world eq | 2.10E+02 | 6.67E+02 | 4.99E+03 | 2.38E+03 | –1.09E+04 | 8.80E+03 | 1.58E+02 |
| **FWM3-V[1]** | Climate change, short term | kg $CO_2$ eq | 1.76E+02 | 1.75E+02 | 1.08E+01 | 6.14E+00 | 1.57E+02 | 2.00E+02 | 3.42E-01 |

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| ASFPM | Impact category | Unit | Average | Median | Standard deviation | Coefficient of variation | 2.50 % | 97.50 % | Standard error of the mean |
|---|---|---|---|---|---|---|---|---|---|
| **FWM3-V[1]** | Fossil and nuclear energy use | MJ deprived | 2.04E+03 | 2.02E+03 | 2.18E+02 | 1.07E+01 | 1.69E+03 | 2.55E+03 | 6.90E+00 |
| **FWM3-V[1]** | Human toxicity cancer | CTUh | 2.77E-04 | 2.58E-04 | 1.15E-04 | 4.17E+01 | 1.18E-04 | 5.82E-04 | 3.65E-06 |
| **FWM3-V[1]** | Land occupation, biodiversity | $m^2$/yr arable | 4.05E+00 | 3.98E+00 | 3.85E-01 | 9.50E+00 | 3.45E+00 | 4.85E+00 | 1.22E-02 |
| **FWM3-V[1]** | Mineral resources use | kg deprived | 1.52E+01 | 1.48E+01 | 2.81E+00 | 1.84E+01 | 1.06E+01 | 2.20E+01 | 8.87E-02 |
| **FWM3-V[1]** | Terrestrial acidification | kg $SO_2$ eq | 1.56E-03 | 1.55E-03 | 1.31E-04 | 8.36E+00 | 1.33E-03 | 1.84E-03 | 4.14E-06 |
| **FWM3-V[1]** | Water scarcity | $m^3$ world eq | −1.17E+02 | 3.58E+02 | 4.59E+03 | −3.91E+03 | −9.91E+03 | 7.51E+03 | 1.45E+02 |
| **FWM4-V[1]** | Climate change, short term | kg $CO_2$ eq | 1.53E+02 | 1.51E+02 | 1.39E+01 | 9.10E+00 | 1.29E+02 | 1.83E+02 | 4.40E-01 |
| **FWM4-V[1]** | Fossil and nuclear energy use | MJ deprived | 1.74E+03 | 1.72E+03 | 2.43E+02 | 1.40E+01 | 1.35E+03 | 2.32E+03 | 7.68E+00 |
| **FWM4-V[1]** | Human toxicity cancer | CTUh | 1.98E-04 | 1.84E-04 | 8.02E-05 | 4.05E+01 | 7.55E-05 | 4.00E-04 | 2.54E-06 |
| **FWM4-V[1]** | Land occupation, biodiversity | $m^2$/yr arable | 2.35E+00 | 2.27E+00 | 4.68E-01 | 1.99E+01 | 1.65E+00 | 3.56E+00 | 1.48E-02 |
| **FWM4-V[1]** | Mineral resources use | kg deprived | 1.12E+01 | 1.09E+01 | 2.01E+00 | 1.80E+01 | 7.96E+00 | 1.57E+01 | 6.36E-02 |
| **FWM4-V[1]** | Terrestrial acidification | kg $SO_2$ eq | 1.23E-03 | 1.22E-03 | 1.45E-04 | 1.18E+01 | 9.85E-04 | 1.56E-03 | 4.59E-06 |
| **FWM4-V[1]** | Water scarcity | $m^3$ world eq | −1.49E+02 | 4.24E+01 | 3.60E+03 | −2.41E+03 | −8.25E+03 | 6.44E+03 | 1.14E+02 |
| **H1-C[1]** | Climate change, short term | kg $CO_2$ eq | 2.65E+03 | 2.64E+03 | 1.51E+02 | 5.70E+00 | 2.38E+03 | 2.96E+03 | 4.77E+00 |
| **H1-C[1]** | Fossil and nuclear energy use | MJ deprived | 3.59E+04 | 3.54E+04 | 4.73E+03 | 1.32E+01 | 2.80E+04 | 4.63E+04 | 1.50E+02 |
| **H1-C[1]** | Human toxicity cancer | CTUh | 1.72E-04 | 1.61E-04 | 6.68E-05 | 3.89E+01 | 8.23E-05 | 3.49E-04 | 2.11E-06 |
| **H1-C[1]** | Land occupation, biodiversity | $m^2$/yr arable | 6.51E+00 | 6.30E+00 | 1.22E+00 | 1.88E+01 | 4.68E+00 | 9.16E+00 | 3.87E-02 |
| **H1-C[1]** | Mineral resources use | kg deprived | 1.73E+01 | 1.69E+01 | 3.72E+00 | 2.14E+01 | 1.19E+01 | 2.62E+01 | 1.17E-01 |
| **H1-C[1]** | Terrestrial acidification | kg $SO_2$ eq | 1.66E-02 | 1.61E-02 | 3.29E-03 | 1.98E+01 | 1.22E-02 | 2.39E-02 | 1.04E-04 |

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| ASFPM | Impact category | Unit | Average | Median | Standard deviation | Coefficient of variation | 2.50 % | 97.50 % | Standard error of the mean |
|---|---|---|---|---|---|---|---|---|---|
| **H1-C[1]** | Water scarcity | m$^3$ world eq | 3.43E+00 | 1.75E+02 | 2.83E+03 | 8.24E+04 | –6.04E+03 | 5.33E+03 | 8.93E+01 |
| **H1-V[1]** | Climate change, short term | kg $CO_2$ eq | 2.49E+03 | 2.48E+03 | 1.48E+02 | 5.97E+00 | 2.23E+03 | 2.81E+03 | 4.69E+00 |
| **H1-V[1]** | Fossil and nuclear energy use | MJ deprived | 3.35E+04 | 3.33E+04 | 4.41E+03 | 1.32E+01 | 2.56E+04 | 4.28E+04 | 1.39E+02 |
| **H1-V[1]** | Human toxicity cancer | CTUh | 1.61E-04 | 1.48E-04 | 6.43E-05 | 3.99E+01 | 7.63E-05 | 3.17E-04 | 2.03E-06 |
| **H1-V[1]** | Land occupation, biodiversity | m$^2$/yr arable | 6.04E+00 | 5.88E+00 | 1.10E+00 | 1.82E+01 | 4.32E+00 | 8.58E+00 | 3.48E-02 |
| **H1-V[1]** | Mineral resources use | kg deprived | 1.63E+01 | 1.58E+01 | 3.43E+00 | 2.10E+01 | 1.14E+01 | 2.38E+01 | 1.09E-01 |
| **H1-V[1]** | Terrestrial acidification | kg $SO_2$ eq | 1.60E-02 | 1.54E-02 | 3.64E-03 | 2.27E+01 | 1.16E-02 | 2.33E-02 | 1.15E-04 |
| **H1-V[1]** | Water scarcity | m$^3$ world eq | 3.99E+01 | 2.31E+02 | 2.77E+03 | 6.94E+03 | –6.28E+03 | 5.13E+03 | 8.77E+01 |
| **H2-C[1]** | Climate change, short term | kg $CO_2$ eq | 1.07E+03 | 1.07E+03 | 7.01E+01 | 6.54E+00 | 9.47E+02 | 1.22E+03 | 2.22E+00 |
| **H2-C[1]** | Fossil and nuclear energy use | MJ deprived | 1.48E+04 | 1.45E+04 | 2.72E+03 | 1.83E+01 | 1.03E+04 | 2.05E+04 | 8.60E+01 |
| **H2-C[1]** | Human toxicity cancer | CTUh | 2.50E-05 | 6.38E-05 | 2.62E-03 | 1.05E+04 | –5.49E-03 | 5.28E-03 | 8.30E-05 |
| **H2-C[1]** | Land occupation, biodiversity | m$^2$/yr arable | 9.95E+01 | 9.11E+01 | 3.43E+01 | 3.45E+01 | 5.67E+01 | 1.84E+02 | 1.09E+00 |
| **H2-C[1]** | Mineral resources use | kg deprived | 1.08E+01 | 1.05E+01 | 1.85E+00 | 1.72E+01 | 8.13E+00 | 1.51E+01 | 5.84E-02 |
| **H2-C[1]** | Terrestrial acidification | kg $SO_2$ eq | 1.30E-02 | 1.27E-02 | 2.05E-03 | 1.57E+01 | 9.64E-03 | 1.80E-02 | 6.48E-05 |
| **H2-C[1]** | Water scarcity | m$^3$ world eq | 7.16E+01 | 1.09E+02 | 1.86E+03 | 2.60E+03 | –3.69E+03 | 3.70E+03 | 5.88E+01 |
| **H2-V[1]** | Climate change, short term | kg $CO_2$ eq | 1.06E+03 | 1.06E+03 | 6.53E+01 | 6.14E+00 | 9.41E+02 | 1.19E+03 | 2.06E+00 |
| **H2-V[1]** | Fossil and nuclear energy use | MJ deprived | 1.46E+04 | 1.44E+04 | 2.61E+03 | 1.78E+01 | 1.02E+04 | 2.06E+04 | 8.24E+01 |
| **H2-V[1]** | Human toxicity cancer | CTUh | 1.83E-04 | 1.64E-04 | 2.51E-03 | 1.37E+03 | –4.57E-03 | 5.71E-03 | 7.94E-05 |
| **H2-V[1]** | Land occupation, biodiversity | m$^2$/yr arable | 8.78E+01 | 8.29E+01 | 2.64E+01 | 3.01E+01 | 5.19E+01 | 1.51E+02 | 8.35E-01 |

SUPPLEMENTARY DATA
Baillet, V., Pauthier, B., Payen, A., Naviaux, P., Symoneaux, R., Chassaing, T., & Renaud-Gentié, C. (2025). Context-Specific Life Cycle Assessment of Active Spring Frost Protection Methods in Viticulture in the Loire Valley and Champagne French Regions. *OENO One*, *59*(1).
https://doi.org/10.20870/oeno-one.2025.59.1.8408

| ASFPM | Impact category | Unit | Average | Median | Standard deviation | Coefficient of variation | 2.50 % | 97.50 % | Standard error of the mean |
|---|---|---|---|---|---|---|---|---|---|
| **H2-V[1]** | Mineral resources use | kg deprived | 1.06E+01 | 1.03E+01 | 1.66E+00 | 1.58E+01 | 7.98E+00 | 1.46E+01 | 5.26E-02 |
| **H2-V[1]** | Terrestrial acidification | kg $SO_2$ eq | 1.28E-02 | 1.26E-02 | 2.11E-03 | 1.65E+01 | 9.23E-03 | 1.75E-02 | 6.68E-05 |
| **H2-V[1]** | Water scarcity | $m^3$ world eq | 2.45E+01 | 7.05E+01 | 1.75E+03 | 7.14E+03 | −3.49E+03 | 3.14E+03 | 5.53E+01 |
| **H3-V[1]** | Climate change, short term | kg $CO_2$ eq | 1.71E+03 | 1.70E+03 | 7.22E+01 | 4.23E+00 | 1.58E+03 | 1.87E+03 | 2.28E+00 |
| **H3-V[1]** | Fossil and nuclear energy use | MJ deprived | 1.59E+04 | 1.55E+04 | 2.75E+03 | 1.73E+01 | 1.13E+04 | 2.21E+04 | 8.68E+01 |
| **H3-V[1]** | Human toxicity cancer | CTUh | 9.57E-05 | 8.91E-05 | 3.58E-05 | 3.74E+01 | 4.86E-05 | 1.88E-04 | 1.13E-06 |
| **H3-V[1]** | Land occupation, biodiversity | $m^2$/yr arable | 3.37E+00 | 3.30E+00 | 5.44E-01 | 1.61E+01 | 2.55E+00 | 4.61E+00 | 1.72E-02 |
| **H3-V[1]** | Mineral resources use | kg deprived | 1.04E+01 | 1.00E+01 | 1.74E+00 | 1.68E+01 | 7.91E+00 | 1.49E+01 | 5.51E-02 |
| **H3-V[1]** | Terrestrial acidification | kg $SO_2$ eq | 1.55E-02 | 1.52E-02 | 2.20E-03 | 1.42E+01 | 1.18E-02 | 2.03E-02 | 6.96E-05 |
| **H3-V[1]** | Water scarcity | $m^3$ world eq | −6.94E+01 | 1.67E+01 | 1.27E+03 | −1.83E+03 | −3.04E+03 | 2.04E+03 | 4.02E+01 |
| **HC1-C[1]** | Climate change, short term | kg $CO_2$ eq | 1.56E+03 | 1.55E+03 | 1.01E+02 | 6.46E+00 | 1.38E+03 | 1.77E+03 | 3.18E+00 |
| **HC1-C[1]** | Fossil and nuclear energy use | MJ deprived | 2.15E+04 | 2.14E+04 | 2.08E+03 | 9.66E+00 | 1.78E+04 | 2.60E+04 | 6.56E+01 |
| **HC1-C[1]** | Human toxicity cancer | CTUh | 4.82E-04 | 4.54E-04 | 1.61E-04 | 3.34E+01 | 2.51E-04 | 8.92E-04 | 5.10E-06 |
| **HC1-C[1]** | Land occupation, biodiversity | $m^2$/yr arable | 3.40E+01 | 3.32E+01 | 6.30E+00 | 1.85E+01 | 2.39E+01 | 4.80E+01 | 1.99E-01 |
| **HC1-C[1]** | Mineral resources use | kg deprived | 3.60E+01 | 3.46E+01 | 7.80E+00 | 2.17E+01 | 2.43E+01 | 5.46E+01 | 2.47E-01 |
| **HC1-C[1]** | Terrestrial acidification | kg $SO_2$ eq | 2.13E-02 | 2.08E-02 | 3.85E-03 | 1.81E+01 | 1.52E-02 | 2.98E-02 | 1.22E-04 |
| **HC1-C[1]** | Water scarcity | $m^3$ world eq | 5.48E+02 | 3.88E+03 | 2.97E+04 | 5.42E+03 | −6.73E+04 | 5.39E+04 | 9.39E+02 |
| **HC1-V[1]** | Climate change, short term | kg $CO_2$ eq | 8.48E+02 | 8.44E+02 | 4.33E+01 | 5.11E+00 | 7.68E+02 | 9.38E+02 | 1.37E+00 |
| **HC1-V[1]** | Fossil and nuclear energy use | MJ deprived | 1.49E+04 | 1.48E+04 | 8.12E+02 | 5.46E+00 | 1.34E+04 | 1.67E+04 | 2.57E+01 |

SUPPLEMENTARY DATA
Baillet, V., Pauthier, B., Payen, A., Naviaux, P., Symoneaux, R., Chassaing, T., & Renaud-Gentié, C. (2025). Context-Specific Life Cycle Assessment of Active Spring Frost Protection Methods in Viticulture in the Loire Valley and Champagne French Regions. *OENO One*, *59*(1). https://doi.org/10.20870/oeno-one.2025.59.1.8408

| ASFPM | Impact category | Unit | Average | Median | Standard deviation | Coefficient of variation | 2.50 % | 97.50 % | Standard error of the mean |
|---|---|---|---|---|---|---|---|---|---|
| **HC1-V**[1] | Human toxicity cancer | CTUh | 2.42E-04 | 2.28E-04 | 7.27E-05 | 3.00E+01 | 1.35E-04 | 4.16E-04 | 2.30E-06 |
| **HC1-V**[1] | Land occupation, biodiversity | $m^2$/yr arable | 1.64E+01 | 1.58E+01 | 3.30E+00 | 2.02E+01 | 1.15E+01 | 2.46E+01 | 1.04E-01 |
| **HC1-V**[1] | Mineral resources use | kg deprived | 1.70E+01 | 1.66E+01 | 2.97E+00 | 1.75E+01 | 1.24E+01 | 2.40E+01 | 9.39E-02 |
| **HC1-V**[1] | Terrestrial acidification | kg $SO_2$ eq | 1.19E-02 | 1.16E-02 | 1.91E-03 | 1.61E+01 | 8.90E-03 | 1.62E-02 | 6.03E-05 |
| **HC1-V**[1] | Water scarcity | $m^3$ world eq | 3.99E+02 | 1.37E+03 | 1.30E+04 | 3.26E+03 | −2.62E+04 | 2.34E+04 | 4.10E+02 |
| **HC2-V**[1] | Climate change, short term | kg $CO_2$ eq | 2.95E+03 | 2.79E+03 | 8.27E+02 | 2.80E+01 | 1.72E+03 | 4.88E+03 | 2.61E+01 |
| **HC2-V**[1] | Fossil and nuclear energy use | MJ deprived | 4.27E+04 | 4.05E+04 | 1.24E+04 | 2.91E+01 | 2.63E+04 | 7.29E+04 | 3.93E+02 |
| **HC2-V**[1] | Human toxicity cancer | CTUh | 5.67E-04 | 5.04E-04 | 3.10E-04 | 5.46E+01 | 1.36E-04 | 1.33E-03 | 9.80E-06 |
| **HC2-V**[1] | Land occupation, biodiversity | $m^2$/yr arable | 5.28E+01 | 4.94E+01 | 1.61E+01 | 3.05E+01 | 3.05E+01 | 9.14E+01 | 5.09E-01 |
| **HC2-V**[1] | Mineral resources use | kg deprived | 4.07E+01 | 3.95E+01 | 9.27E+00 | 2.28E+01 | 2.72E+01 | 6.05E+01 | 2.93E-01 |
| **HC2-V**[1] | Terrestrial acidification | kg $SO_2$ eq | 3.10E-02 | 2.99E-02 | 7.01E-03 | 2.26E+01 | 2.02E-02 | 4.73E-02 | 2.22E-04 |
| **HC2-V**[1] | Water scarcity | $m^3$ world eq | −7.59E+02 | 4.25E+03 | 6.27E+04 | −8.26E+03 | −1.43E+05 | 1.13E+05 | 1.98E+03 |
| **MWM1-C**[1] | Climate change, short term | kg $CO_2$ eq | 1.48E+02 | 1.48E+02 | 7.22E+00 | 4.86E+00 | 1.36E+02 | 1.64E+02 | 2.28E-01 |
| **MWM1-C**[1] | Fossil and nuclear energy use | MJ deprived | 1.85E+03 | 1.84E+03 | 1.81E+02 | 9.76E+00 | 1.55E+03 | 2.27E+03 | 5.72E+00 |
| **MWM1-C**[1] | Human toxicity cancer | CTUh | 2.76E-04 | 2.53E-04 | 1.17E-04 | 4.23E+01 | 1.21E-04 | 5.75E-04 | 3.69E-06 |
| **MWM1-C**[1] | Land occupation, biodiversity | $m^2$/yr arable | 3.64E+00 | 3.58E+00 | 3.38E-01 | 9.30E+00 | 3.15E+00 | 4.46E+00 | 1.07E-02 |
| **MWM1-C**[1] | Mineral resources use | kg deprived | 1.41E+01 | 1.37E+01 | 2.83E+00 | 2.01E+01 | 9.77E+00 | 2.05E+01 | 8.96E-02 |
| **MWM1-C**[1] | Terrestrial acidification | kg $SO_2$ eq | 1.59E-03 | 1.59E-03 | 1.23E-04 | 7.70E+00 | 1.37E-03 | 1.84E-03 | 3.88E-06 |
| **MWM1-C**[1] | Water scarcity | $m^3$ world eq | −2.04E+02 | 1.46E+02 | 4.64E+03 | −2.27E+03 | −1.04E+04 | 8.03E+03 | 1.47E+02 |

**SUPPLEMENTARY DATA**
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| ASFPM | Impact category | Unit | Average | Median | Standard deviation | Coefficient of variation | 2.50 % | 97.50 % | Standard error of the mean |
|---|---|---|---|---|---|---|---|---|---|
| **MWM1-V[1]** | Climate change, short term | kg $CO_2$ eq | 1.39E+02 | 1.38E+02 | 6.98E+00 | 5.04E+00 | 1.26E+02 | 1.54E+02 | 2.21E-01 |
| **MWM1-V[1]** | Fossil and nuclear energy use | MJ deprived | 1.71E+03 | 1.69E+03 | 1.75E+02 | 1.03E+01 | 1.41E+03 | 2.08E+03 | 5.55E+00 |
| **MWM1-V[1]** | Human toxicity cancer | CTUh | 3.32E-04 | 3.09E-04 | 1.34E-04 | 4.02E+01 | 1.47E-04 | 6.61E-04 | 4.22E-06 |
| **MWM1-V[1]** | Land occupation, biodiversity | $m^2$/yr arable | 3.59E+00 | 3.55E+00 | 3.09E-01 | 8.63E+00 | 3.12E+00 | 4.35E+00 | 9.78E-03 |
| **MWM1-V[1]** | Mineral resources use | kg deprived | 1.68E+01 | 1.63E+01 | 3.52E+00 | 2.10E+01 | 1.13E+01 | 2.51E+01 | 1.11E-01 |
| **MWM1-V[1]** | Terrestrial acidification | kg $SO_2$ eq | 1.47E-03 | 1.46E-03 | 1.12E-04 | 7.61E+00 | 1.27E-03 | 1.72E-03 | 3.53E-06 |
| **MWM1-V[1]** | Water scarcity | $m^3$ world eq | –6.89E+01 | 6.12E+02 | 4.92E+03 | –7.14E+03 | –1.18E+04 | 8.41E+03 | 1.56E+02 |
| **MWM2-C[1]** | Climate change, short term | kg $CO_2$ eq | 1.99E+02 | 1.98E+02 | 8.70E+00 | 4.38E+00 | 1.83E+02 | 2.18E+02 | 2.75E-01 |
| **MWM2-C[1]** | Fossil and nuclear energy use | MJ deprived | 2.45E+03 | 2.43E+03 | 2.56E+02 | 1.04E+01 | 2.01E+03 | 3.02E+03 | 8.10E+00 |
| **MWM2-C[1]** | Human toxicity cancer | CTUh | 3.50E-04 | 3.23E-04 | 1.45E-04 | 4.14E+01 | 1.51E-04 | 7.06E-04 | 4.58E-06 |
| **MWM2-C[1]** | Land occupation, biodiversity | $m^2$/yr arable | 3.92E+00 | 3.85E+00 | 3.66E-01 | 9.34E+00 | 3.42E+00 | 4.87E+00 | 1.16E-02 |
| **MWM2-C[1]** | Mineral resources use | kg deprived | 1.84E+01 | 1.80E+01 | 3.62E+00 | 1.97E+01 | 1.24E+01 | 2.65E+01 | 1.15E-01 |
| **MWM2-C[1]** | Terrestrial acidification | kg $SO_2$ eq | 1.76E-03 | 1.75E-03 | 1.33E-04 | 7.51E+00 | 1.54E-03 | 2.06E-03 | 4.19E-06 |
| **MWM2-C[1]** | Water scarcity | $m^3$ world eq | 1.21E+02 | 6.43E+02 | 5.36E+03 | 4.41E+03 | –1.19E+04 | 9.68E+03 | 1.69E+02 |
| **MWM2-V[1]** | Climate change, short term | kg $CO_2$ eq | 1.66E+02 | 1.66E+02 | 8.62E+00 | 5.18E+00 | 1.51E+02 | 1.84E+02 | 2.73E-01 |
| | Fossil and nuclear energy use | MJ deprived | 2.09E+03 | 2.06E+03 | 2.45E+02 | 1.18E+01 | 1.67E+03 | 2.66E+03 | 7.76E+00 |
| **MWM2-V[1]** | Human toxicity cancer | CTUh | 3.64E-04 | 3.28E-04 | 1.53E-04 | 4.20E+01 | 1.58E-04 | 7.74E-04 | 4.83E-06 |
| **MWM2-V[1]** | Land occupation, biodiversity | $m^2$/yr arable | 3.92E+00 | 3.87E+00 | 3.67E-01 | 9.37E+00 | 3.42E+00 | 4.75E+00 | 1.16E-02 |
| **MWM2-V[1]** | Mineral resources use | kg deprived | 1.85E+01 | 1.80E+01 | 3.74E+00 | 2.02E+01 | 1.30E+01 | 2.77E+01 | 1.18E-01 |

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https://doi.org/10.20870/oeno-one.2025.59.1.8408

| ASFPM | Impact category | Unit | Average | Median | Standard deviation | Coefficient of variation | 2.50 % | 97.50 % | Standard error of the mean |
|---|---|---|---|---|---|---|---|---|---|
| **MWM2-V[1]** | Terrestrial acidification | kg $SO_2$ eq | 1.85E-03 | 1.84E-03 | 1.61E-04 | 8.73E+00 | 1.58E-03 | 2.21E-03 | 5.10E-06 |
| **MWM2-V[1]** | Water scarcity | $m^3$ world eq | 1.64E+02 | 5.57E+02 | 5.39E+03 | 3.29E+03 | –1.24E+04 | 9.33E+03 | 1.70E+02 |
| **MWM2-V[1]** | Climate change, short term | kg $CO_2$ eq | 2.23E+03 | 2.21E+03 | 1.73E+02 | 7.75E+00 | 1.95E+03 | 2.62E+03 | 5.47E+00 |
| **WC1-V[2]** | Fossil and nuclear energy use | MJ deprived | 3.09E+04 | 3.02E+04 | 5.07E+03 | 1.64E+01 | 2.35E+04 | 4.30E+04 | 1.60E+02 |
| **WC1-V[2]** | Human toxicity cancer | CTUh | 3.63E-03 | 3.17E-03 | 7.34E-02 | 2.02E+03 | -1.47E-01 | 1.49E-01 | 2.32E-03 |
| **WC1-V[2]** | Land occupation, biodiversity | $m^2$/yr arable | 3.27E+01 | 3.22E+01 | 3.99E+00 | 1.22E+01 | 2.73E+01 | 4.11E+01 | 1.26E-01 |
| **WC1-V[2]** | Mineral resources use | kg deprived | 3.06E+01 | 2.92E+01 | 7.43E+00 | 2.43E+01 | 2.10E+01 | 4.93E+01 | 2.35E-01 |
| **WC1-V[2]** | Terrestrial acidification | kg $SO_2$ eq | 1.01E-02 | 1.01E-02 | 8.70E-04 | 8.60E+00 | 8.70E-03 | 1.20E-02 | 2.75E-05 |
| **WC1-V[2]** | Water scarcity | $m^3$ world eq | 1.67E+03 | 3.26E+03 | 2.80E+04 | 1.68E+03 | –5.82E+04 | 5.21E+04 | 8.85E+02 |

**SUPPLEMENTARY DATA**
Baillet, V., Pauthier, B., Payen, A., Naviaux, P., Symoneaux, R., Chassaing, T., & Renaud-Gentié, C. (2025). Context-Specific Life Cycle Assessment of Active Spring Frost Protection Methods in Viticulture in the Loire Valley and Champagne French Regions. *OENO One*, *59*(1). https://doi.org/10.20870/oeno-one.2025.59.1.8408

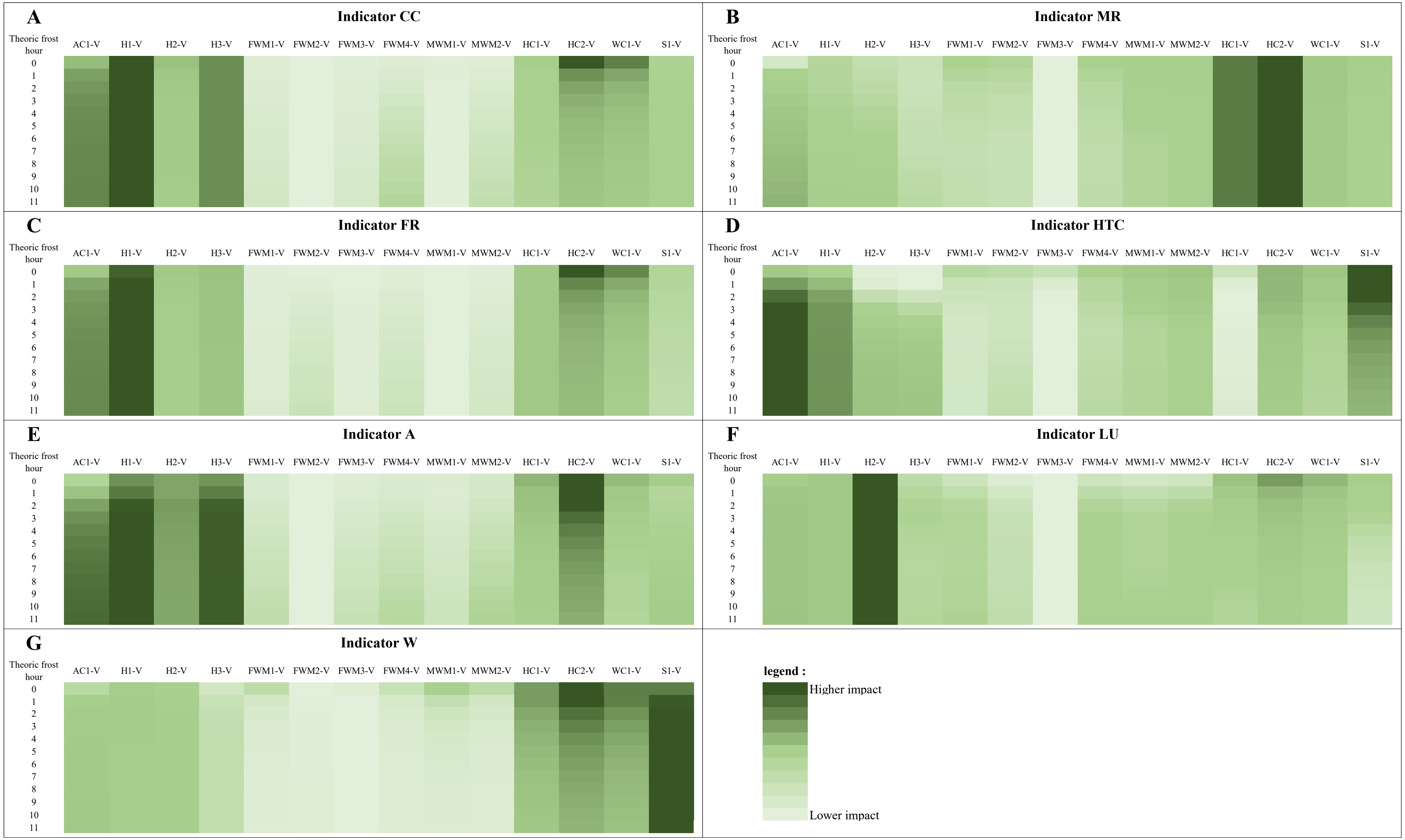

**Figure S1. Comparison of ASFPMs' environmental impacts from the Loire Valley region in the function of yearly spring frost hour occurrences with the EF3.1 characterisation method.**

Seven heatmaps display the ASFPMs' environmental score of the Loire Valley region depending on the frost occurrence. Darker colours correspond to higher scores in the impact category. The frost occurrence varies from 0 to 11 corresponding to the 2018 and 2021 millesimal (Table 2), respectively. A: Climate Change. B: Resource use, minerals and metals. C: Resource use, fossils. D: Human toxicity, cancer. E: Acidification. F: Land use. G: Water use. AC1-V: antifrost candles, Loire Valley region, petrol as raw material. FWM1-V: wind machine, Loire Valley region, fixed machine, diesel fuel, with small heaters. FWM2-V: wind machine, Loire Valley region, fixed, gas fuel, with small heaters. FWM3-V: wind machine, Loire Valley region, fixed, diesel fuel, without small heaters. FWM4-V: wind machine, Loire Valley region, fixed, diesel fuel, with burner. MWM1-V: wind machine, Loire Valley region, mobile, diesel fuel, with small heater and generator. MWM2-V: wind machine, Loire Valley region, mobile, diesel fuel, with a small heater. H1-V: heater, Loire Valley region, fuel as an energy resource. H2-V: heater, Loire Valley region, uses wood as an energy resource. H3-V: heater, Loire Valley region, uses peat as an energy resource. HC1-V: heating cable, Loire Valley region, copper cable. HC2-V: heating cable, Loire Valley region, radiative cable with diode. S1-V: sprinkler, Loire Valley region, 35 $m^3$ of direct water consumption. WC1-V: winter cover, Loire Valley region, non-woven polypropylene cover.

**SUPPLEMENTARY DATA**
Baillet, V., Pauthier, B., Payen, A., Naviaux, P., Symoneaux, R., Chassaing, T., & Renaud-Gentié, C. (2025). Context-Specific Life Cycle Assessment of Active Spring Frost Protection Methods in Viticulture in the Loire Valley and Champagne French Regions. *OENO One*, *59*(1).
https://doi.org/10.20870/oeno-one.2025.59.1.8408

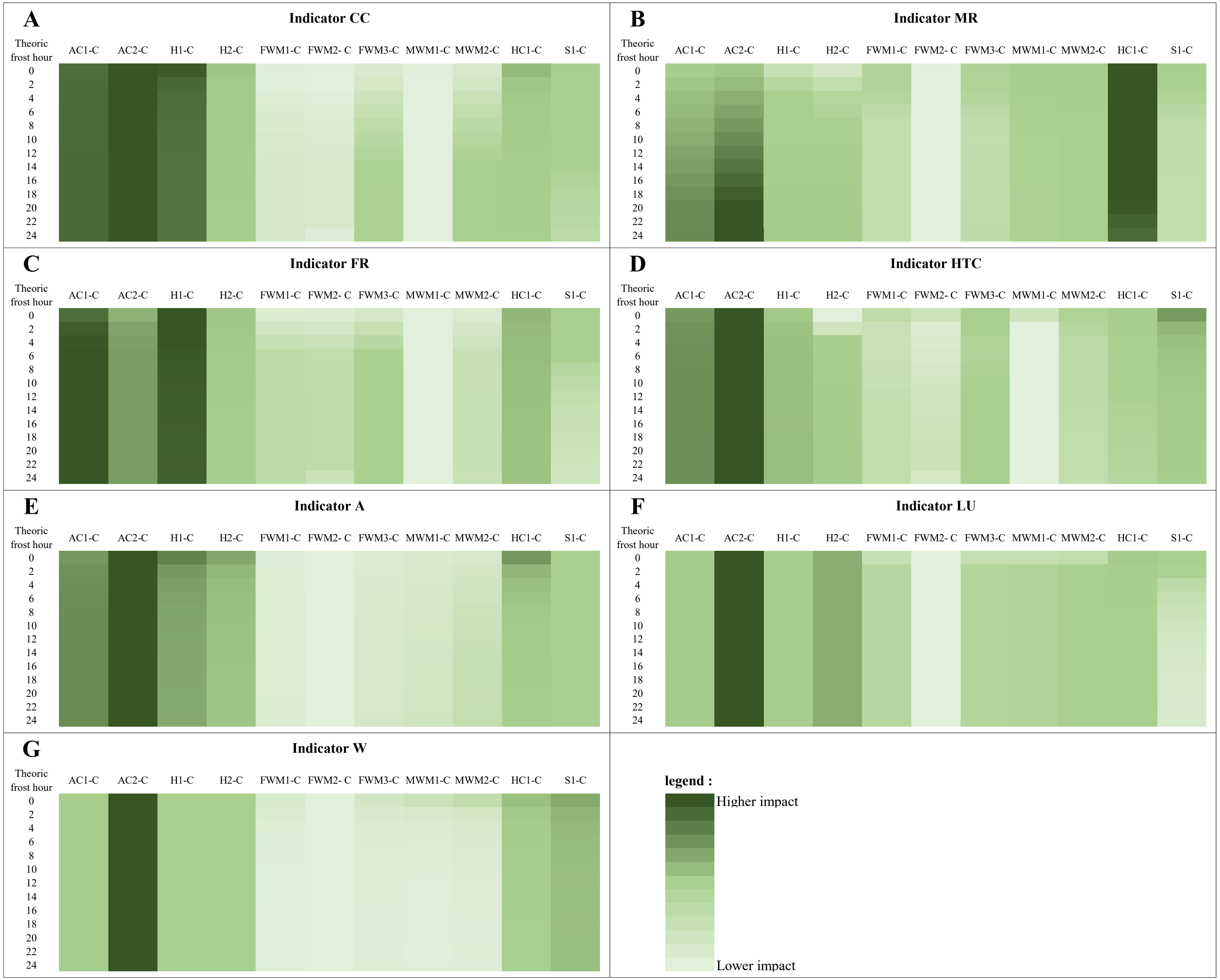

**Figure S2. Comparison of ASFPMs' environmental impacts from the Champagne region in the function of yearly spring frost hour occurrences with the EF3.1 characterisation method.**

Seven heatmaps display the ASFPMs' environmental score of the Champagne region depending on the frost occurrence. Darker colours correspond to higher scores in the impact category. The frost occurrence varies from 0 to 24 corresponding to the 2018 and 2021 millesimal (Table 2), respectively. A: Climate Change. B: Resource use, minerals and metals. C: Resource use, fossils. D: Human toxicity, cancer. E: Acidification. F: Land use. G: Water use. AC1-C: antifrost candles, champagne region, petrol as raw material. AC2-C: antifrost candles, champagne region, palm oil as raw material. FWM1-C: wind machine, Champagne region, fixed machine, gas fuel, with small heaters. FWM2-C: wind machine, Champagne region, fixed machine, gas fuel, without small heaters. FWM3-C: wind machine, Champagne region, fixed machine, gas fuel, with burner. MWM1-C: wind machine, Champagne region, mobile machine, diesel fuel, with a small heater. MWM2-C: wind machine, Champagne region, mobile machine, diesel fuel, with burner. H1-C: heater, Champagne region, fuel as an energy resource. H2-C: heater, Champagne region, wood as an energy resource. HC1-C: heating cable, Champagne region, copper cable. HC1-V: heating cable, Loire Valley region, copper cable. S1-C: sprinkler, Champagne region, 50 $m^3$ of direct water consumption.

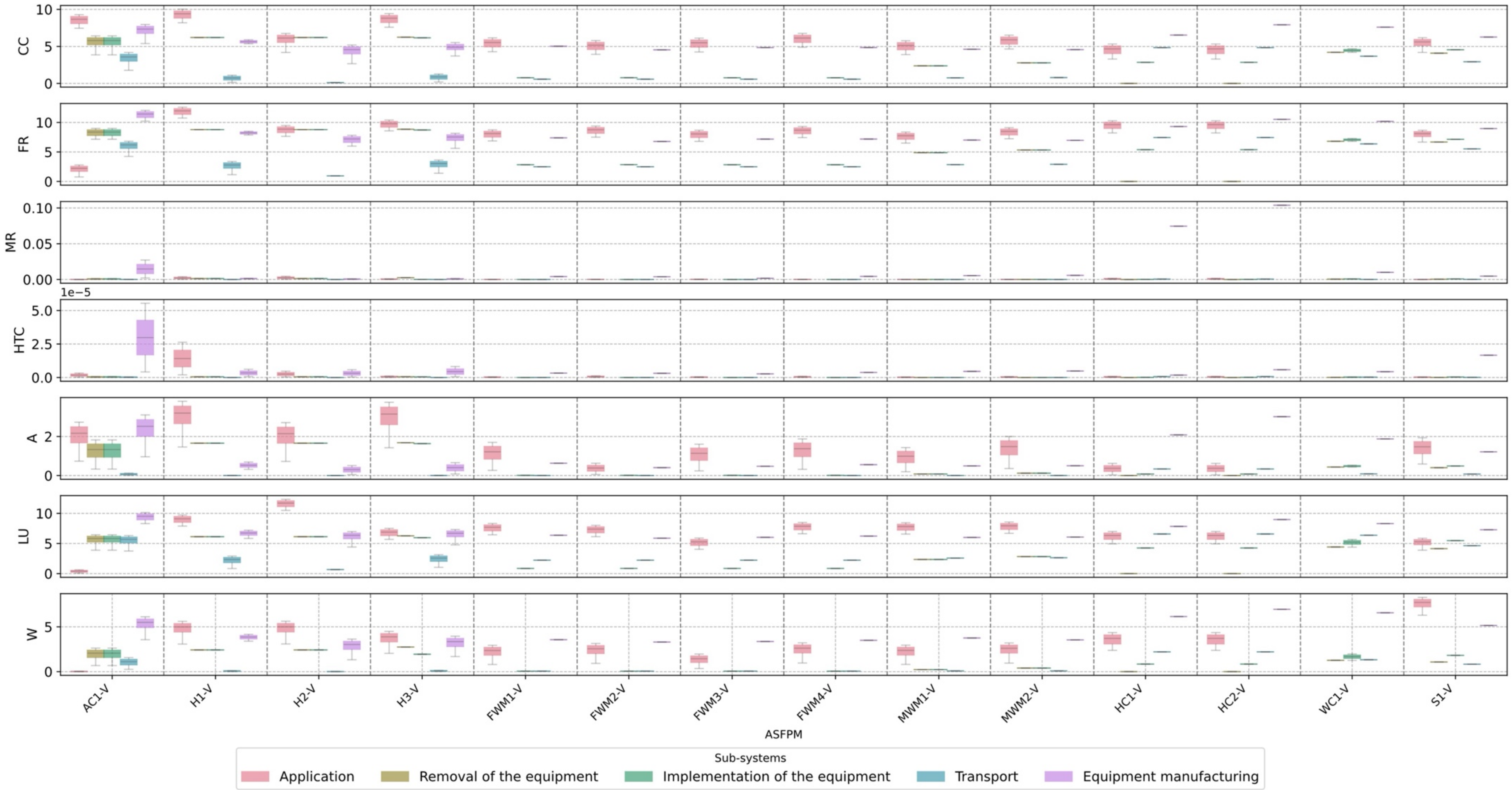
CC
FR
MR
1e−5
HTC
A
LU
W
AC1-V
H1-V
H2-V
H3-V
FWM1-V
FWM2-V
FWM3-V
FWM4-V
MWM1-V
MWM2-V
HC1-V
HC2-V
WC1-V
S1-V
ASFPM
Sub-systems
Application
Removal of the equipment
Implementation of the equipment
Transport
Equipment manufacturing

**Figure S3. Comparison of the sub-system impact's variation for all ASFPMs of the Loire Valley region through the selected LCA indicators with EF3.1 characterisation method.**

CC: Climate change in kg of $CO_2$ eq. FR: Resource use, fossils in MJ. MR: Resource use, mineral and metals in Sb eq. HTC: Human toxicity, cancer in CTUh. A: Acidification in mol H+ eq. LU: Land use in Pt. W: Water use in $m^3$ deprived. The y-axis represents the indicator score in log (1 + specific indicator value) per type of ASFPM technology. AC1-V: antifrost candles, Loire Valley region, petrol as raw material. FWM1-V: wind machine, Loire Valley region, fixed machine, diesel fuel, with small heaters. FWM2-V: wind machine, Loire Valley region, fixed, gas fuel, with small heaters. FWM3-V: wind machine, Loire Valley region, fixed, diesel fuel, without small heaters. FWM4-V: wind machine, Loire Valley region, fixed, diesel fuel, with burner. MWM1-V: wind machine, Loire Valley region, mobile, diesel fuel, with small heater and generator. MWM2-V: wind machine, Loire Valley region, mobile, diesel fuel, with a small heater. H1-V: heater, Loire Valley region, fuel as an energy resource. H2-V: heater, Loire Valley region, uses wood as an energy resource. H3-V: heater, Loire Valley region, uses peat as an energy resource. HC1-V: heating cable, Loire Valley region, copper cable. HC2-V: heating cable, Loire Valley region, radiative cable with diode. S1-V: sprinkler, Loire Valley region, 35 $m^3$ of direct water consumption. WC1-V: winter cover, Loire Valley region, non-woven polypropylene cover.

**SUPPLEMENTARY DATA**
Baillet, V., Pauthier, B., Payen, A., Naviaux, P., Symoneaux, R., Chassaing, T., & Renaud-Gentié, C. (2025). Context-Specific Life Cycle Assessment of Active Spring Frost Protection Methods in Viticulture in the Loire Valley and Champagne French Regions. *OENO One*, *59*(1). https://doi.org/10.20870/oeno-one.2025.59.1.8408

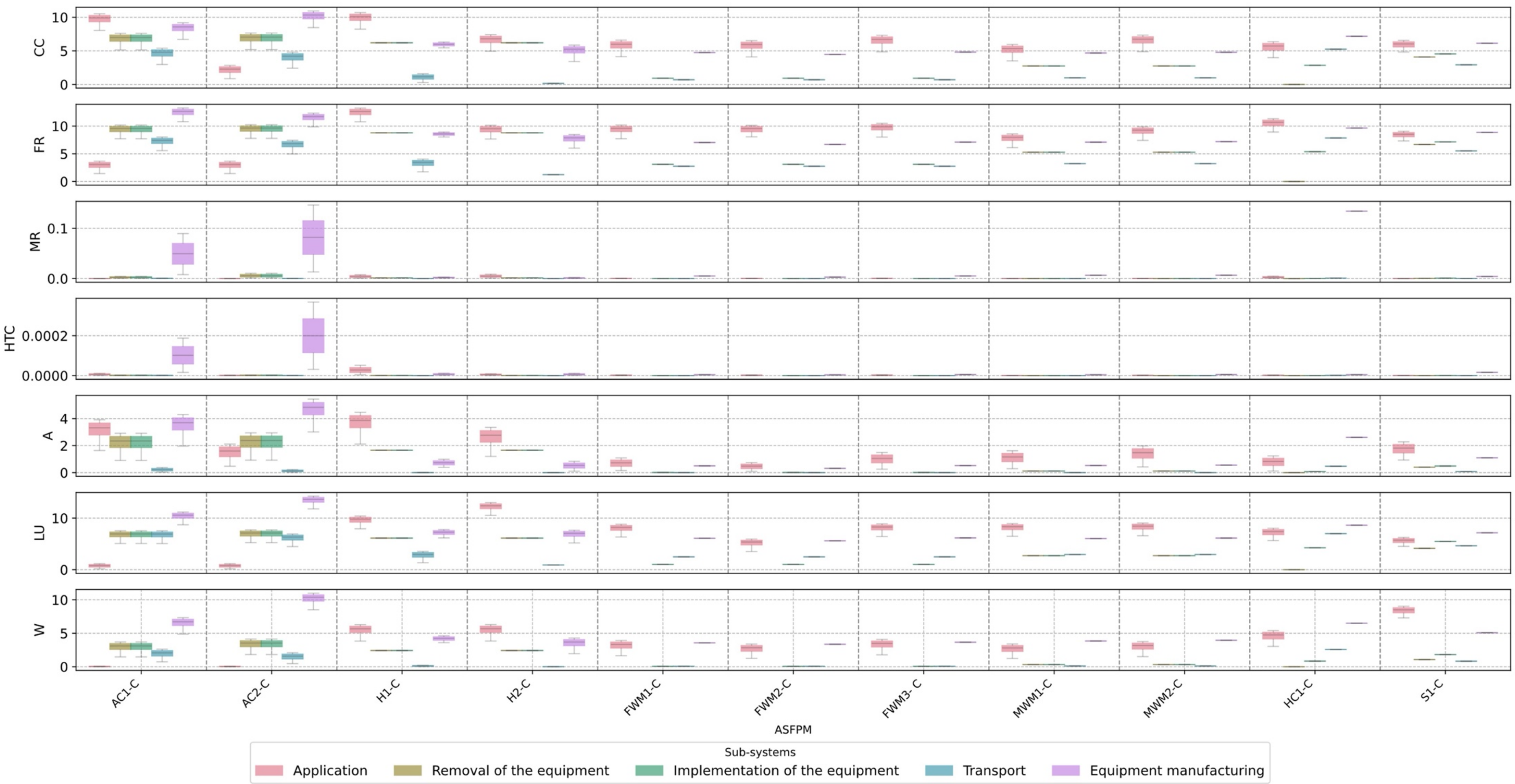

**Figure S4. Comparison of the sub-system impact's variation for all ASFPMs of the Champagne region through the selected LCA indicators with EF3.1 characterisation method.**

CC: Climate change in kg of $CO_2$ eq. FR: Resource use, fossils in MJ. MR: Resource use, mineral and metals in Sb eq. HTC: Human toxicity, cancer in CTUh. A: Acidification in mol H+ eq. LU: Land use in Pt. W: Water use in $m^3$ deprived. The y-axis represents the indicator score in log (1 + specific indicator value) per type of ASFPM technology. AC1-C: antifrost candles, champagne region, petrol as raw material. AC2-C: antifrost candles, champagne region, palm oil as raw material. FWM1-C: wind machine, Champagne region, fixed machine, gas fuel, with small heaters. FWM2-C: wind machine, Champagne region, fixed machine, gas fuel, without small heaters. FWM3-C: wind machine, Champagne region, fixed machine, gas fuel, with burner. MWM1-C: wind machine, Champagne region, mobile machine, diesel fuel, with a small heater. MWM2-C: wind machine, Champagne region, mobile machine, diesel fuel, with burner. H1-C: heater, Champagne region, fuel as an energy resource. H2-C: heater, Champagne region, wood as an energy resource. HC1-C: heating cable, Champagne region, copper cable. S1-C: sprinkler, Champagne region, 50 $m^3$ of direct water consumption.

**SUPPLEMENTARY DATA**
Baillet, V., Pauthier, B., Payen, A., Naviaux, P., Symoneaux, R., Chassaing, T., & Renaud-Gentié, C. (2025). Context-Specific Life Cycle Assessment of Active Spring Frost Protection Methods in Viticulture in the Loire Valley and Champagne French Regions. *OENO One*, *59*(1).
https://doi.org/10.20870/oeno-one.2025.59.1.8408

| | | CC | FR | MR | HTC | A | LU | W |
|---|---|---|---|---|---|---|---|---|
| **Antifrost candle** | *AC1-C* | 2.6E+04 | 3.2E+05 | 5.2E-02 | 1.0E-04 | 7.9E+01 | 3.9E+04 | 8.2E+02 |
| | *AC2-C* | 3.1E+04 | 1.4E+05 | 9.0E-02 | 1.9E-04 | 1.4E+02 | 7.9E+05 | 3.0E+04 |
| | AC1-V | 1.5E+04 | 1.9E+05 | 3.1E-02 | 6.1E-05 | 4.6E+01 | 2.7E+04 | 4.8E+02 |
| **Wind machine** | *FWM1-C* | 4.9E+02 | 1.5E+04 | 5.3E-03 | 5.7E-06 | 1.7E+00 | 3.9E+03 | 6.0E+01 |
| | *FWM2-C* | 4.5E+02 | 1.4E+04 | 3.0E-03 | 5.1E-06 | 9.7E-01 | 4.8E+02 | 4.3E+01 |
| | *FWM3-C* | 8.9E+02 | 1.9E+04 | 5.5E-03 | 6.9E-06 | 2.4E+00 | 4.2E+03 | 6.8E+01 |
| | *MWM1-C* | 3.3E+02 | 4.3E+03 | 6.8E-03 | 4.2E-06 | 3.0E+00 | 4.3E+03 | 6.1E+01 |
| | *MWM2-C* | 9.3E+02 | 1.2E+04 | 7.0E-03 | 6.0E-06 | 4.1E+00 | 4.8E+03 | 7.3E+01 |
| | FWM1-V | 6.2E+02 | 7.9E+03 | 4.4E-03 | 3.8E-06 | 5.4E+00 | 4.7E+03 | 5.3E+01 |
| | FWM2-V | 4.2E+02 | 1.3E+04 | 4.1E-03 | 4.5E-06 | 1.4E+00 | 3.4E+03 | 4.9E+01 |
| | FWM3-V | 5.8E+02 | 7.2E+03 | 2.1E-03 | 3.2E-06 | 4.6E+00 | 7.9E+02 | 3.4E+01 |
| | FWM4-V | 9.9E+02 | 1.2E+04 | 4.7E-03 | 4.8E-06 | 6.3E+00 | 5.4E+03 | 5.6E+01 |
| | MWM1-V | 4.4E+02 | 5.7E+03 | 5.6E-03 | 5.1E-06 | 4.0E+00 | 5.1E+03 | 6.1E+01 |
| | MWM2-V | 8.1E+02 | 1.1E+04 | 6.2E-03 | 5.6E-06 | 7.3E+00 | 5.7E+03 | 5.8E+01 |
| **Heater** | *H1-C* | 2.4E+04 | 2.4E+04 | 2.4E+04 | 2.4E+04 | 2.4E+04 | 2.4E+04 | 2.4E+04 |
| | *H2-C* | 2.0E+03 | 2.8E+04 | 8.1E-03 | 1.2E-05 | 2.3E+01 | 2.3E+05 | 3.3E+02 |
| | H1-V | 2.4E+04 | 2.4E+04 | 2.4E+04 | 2.4E+04 | 2.4E+04 | 2.4E+04 | 2.4E+04 |
| | H2-V | 2.0E+03 | 2.9E+04 | 8.2E-03 | 1.2E-05 | 2.3E+01 | 2.3E+05 | 3.3E+02 |
| | H3-V | 1.4E+04 | 5.0E+04 | 5.1E-03 | 1.0E-05 | 5.1E+01 | 4.3E+03 | 1.6E+02 |
| **Heating Cable** | *HC1-C* | 1.8E+03 | 5.9E+04 | 1.5E-01 | 6.9E-06 | 1.5E+01 | 8.3E+03 | 7.9E+02 |
| | HC1-V | 1.0E+03 | 4.2E+04 | 8.0E-02 | 3.5E-06 | 8.4E+00 | 4.4E+03 | 5.5E+02 |
| | HC2-V | 3.1E+03 | 6.8E+04 | 1.1E-01 | 7.5E-06 | 2.1E+01 | 9.8E+03 | 1.1E+03 |
| **Sprinkler** | *S1-C* | 1.0E+03 | 1.4E+04 | 5.5E-03 | 1.7E-05 | 8.1E+00 | 2.0E+03 | 4.8E+03 |
| | S1-V | 1.2E+03 | 1.6E+04 | 6.1E-03 | 1.8E-05 | 9.5E+00 | 2.2E+03 | 4.2E+03 |
| **Winter Cover** | WC1-V | 2.2E+03 | 2.9E+04 | 1.2E-02 | 5.0E-06 | 6.8E+00 | 5.0E+03 | 7.2E+02 |

**Figure S5. Comparison of ASFPMs for 11 hours of frost within the ASFPM's technologies between optional alternatives and the territory of application with EF3.1 characterisation method.**

FU: to protect 1 ha for 11 hours of frost, except for WC1-V which is to protect 1ha with 11 fold and unfold operations. CC: Climate change in kg of $CO_2$ eq. FR: Resource use, fossils in MJ. MR: Resource use, mineral and metals in Sb eq. HTC: Human toxicity, cancer in CTUh. A: Acidification in mol H+ eq. LU: Land use in Pt. W: Water use in $m^3$ deprived. The environmental scores are in absolute values. Darker colours represent higher scores within the indicator category and the type of technology. Each colour corresponds to a type of ASFPM technology. AC1-C: antifrost candles, champagne region, petrol as raw material. AC2-C: antifrost candles, champagne region, palm oil as raw material. AC1-V: antifrost candles, Loire Valley region, petrol as raw material. FWM1-C: wind machine, Champagne region, fixed machine, gas fuel, with small heaters. FWM2-C: wind machine, Champagne region, fixed machine, gas fuel, without small heaters. FWM3-C: wind machine, Champagne region, fixed machine, gas fuel, with burner. MWM1-C: wind machine, Champagne region, mobile machine, diesel fuel, with a small heater. MWM2-C: wind machine, Champagne region, mobile machine, diesel fuel, with burner. FWM1-V: wind machine, Loire Valley region, fixed machine, diesel fuel, with small heaters. FWM2-V: wind machine, Loire Valley region, fixed, gas fuel, with small heaters. FWM3-V: wind machine, Loire Valley region, fixed, diesel fuel, without small heaters. FWM4-V: wind machine, Loire Valley region, fixed, diesel fuel, with burner. MWM1-V: wind machine, Loire Valley region, mobile, diesel fuel, with small heater and generator. MWM2-V: wind machine, Loire Valley region, mobile, diesel fuel, with a small heater. H1-C: heater, Champagne region, fuel as an energy resource. H2-C: heater, Champagne region, wood as an energy resource. H1-V: heater, Loire Valley region, fuel as an energy resource. H2-V: heater, Loire Valley region, uses wood as an energy resource. H3-V: heater, Loire Valley region, uses peat as an energy resource. HC1-C: heating cable, Champagne region, copper cable. HC1-V: heating cable, Loire Valley region, copper cable. HC2-V: heating cable, Loire Valley region, radiative cable with diode. S1-C: sprinkler, Champagne region, 50 $m^3$ of direct water consumption. S1-V: sprinkler, Loire Valley region, 35 $m^3$ of direct water consumption. WC1-V: winter cover, Loire Valley region, non-woven polypropylene cover.