Military Emissions Gap Conference 2023

MILITARY AND CONFLICT GHG EMISSIONS:
FROM UNDERSTANDING TO MITIGATION

Tuesday 26 September, University of Oxford, and online
Poll question

How do you think emissions caused by Russia’s war are distributed over the different sectors?

- Warfare
- Fires
- Future reconstruction
- Other

**CHOICE 1**
- Warfare: 60%
- Fires: 10%
- Future reconstruction: 5%
- Other: 25%

**CHOICE 2**
- Warfare: 40%
- Fires: 20%
- Future reconstruction: 15%
- Other: 25%

**CHOICE 3**
- Warfare: 20%
- Fires: 15%
- Future reconstruction: 40%
- Other: 25%

**CHOICE 4**
- Warfare: 20%
- Fires: 40%
- Future reconstruction: 15%
- Other: 25%
Climate Damage caused by Russia’s war in Ukraine

Initiative on GHG accounting of war

*Military and Conflict Emissions Conference*
*from understanding to mitigation*
*Oxford, 26 September 2023*
Proposed scopes of military greenhouse gas emissions

Scope 1:
- Military facilities
- Equipment use
- Fugitive emissions
- Use and disposal of munitions

Scope 2:
- Purchased energy

Scope 3:
- Capital goods
- Purchased goods and services
- Building and construction

Scope 3+:
- Transportation of goods
- Waste management
- Business travel and commuting
- Leased assets
- Land and estate management
- Bunker fuels
- Building and construction (in theatre)
- Waste (in theatre)
- Landscape fires
- Infrastructure damage

Other:
- Debris
- Reconstruction
- Soil degradation
- Land-use changes
- Remediation
- Medical care
- Displacement of people

Aviation contrails
War as a ‘carbon project’

Three elements of a carbon project:

- Starting date
- Project boundary
- Baseline vs. project emissions

Starting date = Full-scale invasion on 24 February 2022

Project boundary:

- Geographical boundary: War theatre only or beyond?
- Direct emissions or indirect (embodied carbon) as well?
- Only past emissions or include future emissions?
- How to attribute events to the act of aggression?
Breakdown of sources (MtCO₂e)

- Warfare: 14.6
- Fires: 21.9
- Refugees: 17.7
- Civil aviation: 2.7
- Civilian Infrastructure: 50.2
- Nord Stream 1 & 2: 12
Energy sector, aviation and country impact

<table>
<thead>
<tr>
<th>Natural gas</th>
<th>Gas-to-oil</th>
<th>Power</th>
<th>Pipeline-to-LNG</th>
<th>Net effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>-61.4</td>
<td>21.3</td>
<td>14.4</td>
<td>22.9</td>
<td>-2.9</td>
</tr>
</tbody>
</table>

Map showing distances and years:
- Tokyo: 11h, 2021
- London: 15h, 2022
- Ukraine
- Europe
- The World
**Hold the aggressor accountable**

Compensation mechanism:

- Make GHG emissions (climate damage) a category of the International Register of Damages (part of the International Compensation Mechanism of the Council of Europe)

Existing courts:

- International Court of Justice or International Criminal Court

UNFCCC:

- Account or compensate for these war emissions

Use the proceeds to mitigate emissions through a green recovery, e.g. minimize future reconstruction emissions
Next steps

COP28:
- Third report covering 555 days of war
- Climate Damage litigation
- Low-carbon recovery

Research agenda:
- Improve methodologies / alignment with IPCC guidelines
- Conflict emissions: will they be recorded in National Inventories?
- Other burst events: emissions from large military exercises


Contact: Lennard de Klerk, +36 30 3662983, lennard@klunen.com
Military Emissions Gap Conference 2023

MILITARY AND CONFLICT GHG EMISSIONS: FROM UNDERSTANDING TO MITIGATION

Tuesday 26 September, University of Oxford, and online

CONCRETE IMPACTS  Conflict and Environment Observatory  Scientists for Global Responsibility  UNIVERSITY OF OXFORD  Queen Mary University of London  The Minor Foundation for the Major Challenges
Warfare emissions caused by Russia’s war in Ukraine
(24 February 2022 – 23 February 2023)

Initiative on GHG accounting of war

Military Emissions Gap Conference 2023

26 September 2023
Fog of war:

What GHGs emissions to count?
How to get activity data?
Which emission factors to use?
How have we assessed warfare emissions?

- **Step-by-step approach**: apply the helicopter view to map the key sources of emissions first and gradually extend the depth and scope of accounting.

- **Finding allies and building alliances**: bringing together expertise from various fields (e.g. military, carbon accounting) and sectors (e.g. academics, OSINT community, think-tanks, journalists, etc.)

- **Gradual improvement of the accuracy**: focus on understanding the scale and the structure of warfare emissions sources and improve accuracy in the process where possible.
Warfare emissions in total estimated climate damage (MtCO$_2$e)
Warfare emissions by sources (MtCO$_2$e)

- Pre-invasion force accumulation: 0.1
- Fuel consumption by Russian troops: 14.1
- Fuel consumption by Ukrainian troops: 4.7
- Use of ammunition: 2
- Military equipment: 0.9
- Construction of fortifications: 0.1

**Total emissions:** 21.9
• **18.8 MtCO$_{2e}$** of GHGs emissions during the first year of the war, including direct emissions from combustion and upstream emissions.

• Structure of fuel consumption depends on the nature of war and operations, including on the intensity of aviation use.

• No reliable activity data on fuel consumption: different top-down and bottom-up approaches were used for estimates.

• Average value from two different top-down approaches (based on reported fuel supplies via railway and personnel involved) was used in calculations.

• Bottom-up approach was used to test the reasonability of the estimates.
Emissions from logistical “tale” could be several times higher than emissions from “fighting tooth”.

Photo: Ministry of Defense of Ukraine, @DefenceU on X
Ammunition

- **2 MtCO$_2$e** of GHGs emissions from the use of artillery ammunition, other ammunition and explosives.

- Lifecycle approach: GHG emissions from manufacturing of ammunition and relevant raw materials, combustion of the propellant during firing, and detonation of the warhead at the point of impact.

- Estimates of artillery use intensity by both sides of the war during different periods of the war were used as key activity data.

- Research on lifecycle environmental impact of 155mm artillery shell along with carbon footprint of steel elements were used as emission factors.
Almost 98% of GHG emissions occur during manufacturing of ammunition and raw materials, while the remaining small fraction occurs during the use phase.
Fortifications

- **0.1 MtCO$_2$e** of GHGs emissions due to manufacturing of concrete and other materials used for the construction of fortifications

- Hundreds of kilometers of “dragon’s teeth” lines and hundreds thousand tons of carbon intensive concrete used

- Other emissions from the use of steel elements and construction
Military equipment

- **0.9 MtCO$_2$e** of GHGs emissions from the manufacturing of destroyed and damaged military equipment.

- Manufacturing of all machinery requires structural steels, alloyed steels, cast materials, light alloys, synthetic materials, and other carbon-intensive resources.

- Limited research is available on the carbon footprint of military equipment manufacturing and proxy estimates for other types of equipment have been applied.

- Military equipment manufacturers start reporting their carbon footprint data but limit the coverage to Scope 1 and Scope 2 emissions and do not provide data on the most significant Scope 3 emission categories, such as emissions from the manufacturing of materials and product use.
Key takeaways

- Warfare emissions are very significant and only a fraction of them occur on the battlefield. Supply chain emissions could be two to five times higher than operational emissions of the military.

- Significant volumes of emissions occur during manufacturing of ammunition and explosives, military equipment and machinery, as well as from fuel consumption of military logistical systems.

- While governments and businesses are struggling with achieving required volumes of GHGs emissions reduction Russia’s invasion of Ukraine causes millions tons of additional emissions, redirects financial resources and puts at risk climate mitigation and adaptation efforts.

Download full report:  https://en.ecoaction.org.ua/publication

Updated report will be presented at COP28
In Memoriam: Oleksii Khabatiuk

(19 September 1977 – 4 May 2023)
Military Emissions Gap Conference 2023

MILITARY AND CONFLICT GHG EMISSIONS: FROM UNDERSTANDING TO MITIGATION

Tuesday 26 September, University of Oxford, and online
Wildfires caused by rocket launchers and artillery / mortars

Mykolaiv Oblast, 9 August 2022
Wildfires caused by rocket launchers and artillery / mortars
Landscape fires related with Russian military invasion

Legend
- Red: Landscape Fires
- Pink: Zone of active armed conflict

Land Cover
- Green: Coniferous forests
- Dark green: Broadleaved forests
- Yellow: Other natural landscapes
- Light yellow: Croplands
- Purple: Urban-industrial areas

Source of data:
- ORSRA Initiative Service
- Copernicus
- SES mine action service

Prepared with the support of Zoi Environment Network

Period: February 24, 2022 - February 28, 2023
Methods: fire mapping

• Surface reflectance time series of Sentinel 2 imagery (Level 2A) were used to map fire perimeters based on ignition locations and dates of fires (14-days time window).

• Distribution of burned land cover types within fire perimeters were mapped using the Copernicus Dynamic Land Cover map (100 m resolution of 2019).

• Burn severity was mapped using the delta NBR (dNBR, Normalized Burn Ration) approach. Pre-fire image mosaics were created by selecting those pixels that had the highest NBR values in 40-day window before fires.

• The dNBR values were calculated within 5, 10, 15, …, 40 days intervals after fires.

• We calculated for all regions of Ukraine average values of burn severity classes by land cover types (coniferous, deciduous forests, croplands, other natural vegetation).
Methods: carbon emissions from forest fires

- Determine the species and age structure of forest stands based on the data of the current forest inventory of Ukraine for each region of Ukraine
- Estimate the total volume of biomass based on biomass models: coniferous (pine, spruce), deciduous (oak, beech, birch, aspen, and alder)
- Estimate the volume of biomass losses as a result of forest fires of different severity
- Surface, canopy (crown) or combined forest fires form different degrees of damage. This step in the carbon emission estimation algorithm is based on available fragmentary scientific data and expert assessments
Methods: fires on croplands and grasslands

• Determination of the dominant species structure of the sown areas of agricultural crops
• Estimation of yield and volume of biomass of agricultural crops within each oblast is determined on the basis of national statistics data
• The amount of biomass is determined by the coefficients of the total yield of surface and root residues of agricultural crops depending on the yield of the main products
• Estimation of biomass losses as a result of fires of different severity
• In the 60-km buffer zone during May-July biomass losses due to a high density of shelling
## Results

<table>
<thead>
<tr>
<th>Land category</th>
<th>Burned area, ha</th>
<th>Biomass loss, t</th>
<th>Biomass loss, t·ha⁻¹</th>
<th>Carbon loss, t</th>
<th>Carbon loss, t·ha⁻¹</th>
<th>CO₂ emission, t</th>
<th>Other GHG, t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coniferous Forest</td>
<td>31126.5</td>
<td>331915.2</td>
<td>10.66</td>
<td>142718</td>
<td>4.59</td>
<td>523298</td>
<td>50553</td>
</tr>
<tr>
<td>Cropland</td>
<td>419123.9</td>
<td>1904697.5</td>
<td>4.54</td>
<td>857114</td>
<td>2.05</td>
<td>3142751</td>
<td>151516</td>
</tr>
<tr>
<td>Other Forest</td>
<td>25540.3</td>
<td>165735.6</td>
<td>6.49</td>
<td>68741</td>
<td>2.69</td>
<td>252051</td>
<td>24349</td>
</tr>
<tr>
<td>Other Natural Vegetation</td>
<td>273745.2</td>
<td>775811.7</td>
<td>2.83</td>
<td>349115</td>
<td>1.28</td>
<td>1280089</td>
<td>61715</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>749535.9</strong></td>
<td><strong>3178160</strong></td>
<td><strong>4.33</strong></td>
<td><strong>1417688</strong></td>
<td><strong>1.89</strong></td>
<td><strong>5198189</strong></td>
<td><strong>288133</strong></td>
</tr>
</tbody>
</table>
Discussion: uncertainties and needs in collecting field data

• For the moment only few studies were devoted to the carbon emissions assessment from landscape fires during war in Ukraine that were related to big gaps in data to provide such calculations

• Among them the most completed assessment of the joint team of de Klerk et al., 2022, 2023

• Good overview of the problems and assessments done in Politico’s article “There’s a Battle Over Carbon Emerging from the War in Ukraine” from 9.03.2023

• Burnt factor coefficients of forest biomass losses as a result of forest fires contains uncertainties

• Distribution of stands by composition and age according to forest inventory data may not fully correspond to the area of damaged stands

• Not all surface fires of low intensity are taken into account
Conclusions

• Carbon dioxide emissions from landscape fires during 2022 in Ukraine reached 5.48 million tons.

• The largest amount of carbon emissions occurred during fires on croplands (59%) and grasslands that are not cultivated (24%). Forest fires emitted more than 16.9% of total carbon emissions (12.6% from fires in pine forests and 4.3% in deciduous and mixed forests).

• Average carbon losses per 1 ha during fires in coniferous forests were more than 2 times higher compared to other landscape types and deciduous forests.
Military Emissions Gap Conference 2023

MILITARY AND CONFLICT GHG EMISSIONS: FROM UNDERSTANDING TO MITIGATION

Tuesday 26 September, University of Oxford, and online
Tracking unaccounted greenhouse gas emissions due to the war in Ukraine since 2022

Rostyslav Bun
Lviv Polytechnic National University, Ukraine
WSB University, Poland
### Countries with the highest GHG emissions

<table>
<thead>
<tr>
<th>Country</th>
<th>CO₂ emissions 2019 (Mt)</th>
<th>CO₂ emissions 2020 (Mt)</th>
<th>CO₂ per capita 2019 (tons)</th>
<th>CO₂ per capita 2020 (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>9,876.50</td>
<td>8,204.00</td>
<td>7.1</td>
<td>6.4</td>
</tr>
<tr>
<td>United States</td>
<td>4,744.50</td>
<td>4,255.90</td>
<td>14.4</td>
<td>13.0</td>
</tr>
<tr>
<td>India</td>
<td>2,310</td>
<td>2,118</td>
<td>1.7</td>
<td>1.7</td>
</tr>
<tr>
<td>Russia</td>
<td>1,640.30</td>
<td>1,555.90</td>
<td>11.4</td>
<td>10.8</td>
</tr>
<tr>
<td>Japan</td>
<td>1,056.20</td>
<td>1,024.10</td>
<td>8.4</td>
<td>8.2</td>
</tr>
<tr>
<td>Germany</td>
<td>644.10</td>
<td>585.30</td>
<td>7.8</td>
<td>7.3</td>
</tr>
<tr>
<td>South Korea</td>
<td>585.70</td>
<td>570.70</td>
<td>11.3</td>
<td>10.5</td>
</tr>
<tr>
<td>Iran</td>
<td>585.70</td>
<td>570.70</td>
<td>7.3</td>
<td>7.1</td>
</tr>
<tr>
<td>Indonesia</td>
<td>585.70</td>
<td>628.60</td>
<td>2.2</td>
<td>2.3</td>
</tr>
<tr>
<td>Canada</td>
<td>571</td>
<td>523.20</td>
<td>15.2</td>
<td>13.8</td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>405.20</td>
<td>354.40</td>
<td>14.5</td>
<td>13.4</td>
</tr>
<tr>
<td>South Africa</td>
<td>433.60</td>
<td>381.40</td>
<td>11.2</td>
<td>10.0</td>
</tr>
<tr>
<td>Mexico</td>
<td>419.40</td>
<td>351.40</td>
<td>38.1</td>
<td>33.5</td>
</tr>
<tr>
<td>Brazil</td>
<td>411</td>
<td>366.40</td>
<td>385</td>
<td>336</td>
</tr>
<tr>
<td>Turkey</td>
<td>366.40</td>
<td>306.40</td>
<td>366</td>
<td>306</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>342.20</td>
<td>266.80</td>
<td>306</td>
<td>266</td>
</tr>
</tbody>
</table>

**Share in 2022 global emissions, yearly GHG emission relative changes**

Source: https://worldpopulationreview.com/country-rankings/greenhouse-gas-emissions-by-country

### 2023 Annex I Party GHG Inventory Submissions to the UNFCCC

<table>
<thead>
<tr>
<th>Party</th>
<th>Date of CRF original submission</th>
<th>Latest submitted NIR</th>
<th>Latest submitted CRT</th>
<th>Latest submitted SEF</th>
<th>Status Report</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>13 April 2023</td>
<td>NIR 13 Apr 2023</td>
<td>CRT 13 Apr 2023</td>
<td>SEF-CPI-2022</td>
<td>14 Apr 2023</td>
</tr>
<tr>
<td>Austria</td>
<td>13 April 2023</td>
<td>NIR 13 Apr 2023</td>
<td>CRT 13 Apr 2023</td>
<td>SEF-CPI-2022</td>
<td>14 Apr 2023</td>
</tr>
<tr>
<td>Belarus</td>
<td>16 April 2023</td>
<td>NIR 16 Apr 2023</td>
<td>CRT 16 Apr 2023</td>
<td>SEF-CPI-2022</td>
<td>14 Apr 2023</td>
</tr>
<tr>
<td>Belgium</td>
<td>16 April 2023</td>
<td>NIR 16 Apr 2023</td>
<td>CRT 16 Apr 2023</td>
<td>SEF-CPI-2022</td>
<td>14 Apr 2023</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>12 April 2023</td>
<td>NIR 12 Apr 2023</td>
<td>CRT 12 Apr 2023</td>
<td>SEF-CPI-2022</td>
<td>14 Apr 2023</td>
</tr>
<tr>
<td>Canada</td>
<td>16 April 2023</td>
<td>NIR 16 Apr 2023</td>
<td>CRT 16 Apr 2023</td>
<td>SEF-CPI-2022</td>
<td>14 Apr 2023</td>
</tr>
</tbody>
</table>

**TABLE 1 SECTORAL REPORT FOR ENERGY**

(Sheet 1 of 2)

<table>
<thead>
<tr>
<th>GREENHOUSE GAS SOURCE AND SINK CATEGORIES</th>
<th>CO₂ (kt)</th>
<th>CH₄ (kt)</th>
<th>N₂O (kt)</th>
<th>NOₓ (kt)</th>
<th>CO (kt)</th>
<th>NMVOC (kt)</th>
<th>SO₂ (kt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Energy</td>
<td>159735.73</td>
<td>1939.04</td>
<td>5.14</td>
<td>551.04</td>
<td>721.18</td>
<td>521.09</td>
<td>615.83</td>
</tr>
<tr>
<td>A. Fuel combustion activities (sectoral approach)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Energy industries</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Public electricity and heat production</td>
<td>84810.85</td>
<td>3.52</td>
<td>1.13</td>
<td>173.67</td>
<td>33.15</td>
<td>4.05</td>
<td>481.27</td>
</tr>
<tr>
<td>b. Petroleum refining</td>
<td>80546.68</td>
<td>2.76</td>
<td>0.91</td>
<td>166.15</td>
<td>30.46</td>
<td>3.86</td>
<td>474.33</td>
</tr>
<tr>
<td>2. Manufacturing industries and construction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Iron and steel</td>
<td>11351.73</td>
<td>0.72</td>
<td>0.10</td>
<td>18.32</td>
<td>38.34</td>
<td>7.97</td>
<td>55.19</td>
</tr>
<tr>
<td>b. Non-ferrous metals</td>
<td>925.92</td>
<td>0.05</td>
<td>0.01</td>
<td>1.45</td>
<td>4.34</td>
<td>0.60</td>
<td>3.95</td>
</tr>
<tr>
<td>c. Chemicals</td>
<td>412.51</td>
<td>0.04</td>
<td>0.00</td>
<td>0.57</td>
<td>0.36</td>
<td>0.19</td>
<td>0.11</td>
</tr>
<tr>
<td>d. Pulp, paper and print</td>
<td>112.37</td>
<td>0.00</td>
<td>0.00</td>
<td>0.07</td>
<td>0.03</td>
<td>0.02</td>
<td>0.00</td>
</tr>
<tr>
<td>e. Food processing, beverages and tobacco</td>
<td>579.05</td>
<td>0.03</td>
<td>0.00</td>
<td>0.87</td>
<td>1.50</td>
<td>0.40</td>
<td>1.04</td>
</tr>
<tr>
<td>f. Non-metallic minerals</td>
<td>4719.70</td>
<td>0.36</td>
<td>0.05</td>
<td>9.15</td>
<td>29.67</td>
<td>3.61</td>
<td>275.37</td>
</tr>
<tr>
<td>g. Other (please specify)</td>
<td>2908.26</td>
<td>0.11</td>
<td>0.01</td>
<td>4.63</td>
<td>3.43</td>
<td>1.75</td>
<td>1.05</td>
</tr>
<tr>
<td>3. Transport</td>
<td>23237.59</td>
<td>8.08</td>
<td>3.70</td>
<td>311.98</td>
<td>559.77</td>
<td>386.21</td>
<td>36.94</td>
</tr>
<tr>
<td>a. Domestic aviation</td>
<td>1.58</td>
<td>0.00</td>
<td>0.01</td>
<td>0.55</td>
<td>0.28</td>
<td>0.08</td>
<td>0.05</td>
</tr>
<tr>
<td>b. Road transportation</td>
<td>24351.21</td>
<td>8.35</td>
<td>1.42</td>
<td>140.83</td>
<td>407.83</td>
<td>69.15</td>
<td>24.37</td>
</tr>
<tr>
<td>c. Railways</td>
<td>376.68</td>
<td>0.02</td>
<td>0.15</td>
<td>5.73</td>
<td>4.78</td>
<td>0.96</td>
<td>8.25</td>
</tr>
<tr>
<td>d. Domestic navigation</td>
<td>82.33</td>
<td>0.01</td>
<td>0.00</td>
<td>1.54</td>
<td>0.62</td>
<td>0.21</td>
<td>0.54</td>
</tr>
<tr>
<td>e. Other transportation</td>
<td>7539.53</td>
<td>0.70</td>
<td>2.13</td>
<td>163.32</td>
<td>146.27</td>
<td>314.92</td>
<td>97.38</td>
</tr>
</tbody>
</table>

Source: [https://unfccc.int/ghg-inventories-annex-i-parties/2023](https://unfccc.int/ghg-inventories-annex-i-parties/2023)
The war suddenly overrides the enormous efforts of many scientists and policy makers.

These emissions will never be reported in NIRs!!!
Overriding reporting system: This is not a new problem

Gulf war (1991): Kuwait oil fires

Area: 43,300 km² ( > the Netherlands’ area 41,500 km²)

Industrial regions: iron and steel production, cokes, coal mining etc.

Ukraine’s NIRs for 2014-2021:

“... for emission and reduction estimations on temporarily occupied by the Russian Federation territory of Ukraine expert estimation was performed ...”

What with uncertainty of such an estimate?
GHG emissions caused by military actions in Ukraine that have a chance of not being accounted for in official national reporting.
1. The use of bombs, missiles, barrel artillery, mines, and small arms

GHG emissions occur during:
- firing (barrel artillery and small arms),
- flight to the destination (missiles and drones),
- explosions (missiles, bombs, shells, grenades, drones, and mines).

18 months of the war:
Emissions – 283.3 ktCO$_2$

2. The use of petroleum products for military actions

Both armies:
armored combat vehicles, self-propelled artillery system, tanks, multiple launch rocket systems, aircrafts, helicopters, trucks, ships etc.

18 months of the war:
Emissions – 28.69 MtCO$_2$-eq., including:
26.80 MtCO$_2$-eq. from the land military vehicles,
1.03 MtCO$_2$-eq. from aviation,
0.86 MtCO$_2$-eq. from ships.
3. Fires of petroleum products at petroleum storage depots

Destroyed due to missile attacks and shelling:
- petroleum storage depots,
- oil refineries,
- petroleum stations,
- petrol trucks.

Occupied as well as not-occupied territories.

18 months of the war:
Emissions – 5.43 MtCO$_2$-eq.

4. Fires in buildings and other infrastructure

Wooden constructions and things:
- floors, windows and doors, furniture, roof constructions,
- auxiliary buildings, fences, etc.

Other combustible materials:
- plastics, fabrics, clothes/shoes, books, etc.

18 months of the war:
Emissions – 18.15 MtCO$_2$-eq., including:
- 17.80 Mt CO$_2$,
- 5.0 kt CH$_4$,
- and 0.73 kt N$_2$O.
5. Emissions from forest fires and fires of agricultural lands

- Forest fires emissions – 16.68 MtCO₂-eq., including:
  - 14.84 Mt CO₂, 44.5 kt CH₄, and 2.46 kt N₂O;
- Fires of agricultural lands – 6.44 MtCO₂-eq., including:
  - 5.73 Mt CO₂, 17.2 kt CH₄, and 0.95 kt N₂O;
- Fires of other nature landscapes – 646 kt CO₂-eq.

Forest fires as a result of shelling:
Kherson, Mykolaiv, Kyiv, Chernihiv, Sumy, Kharkiv, Donetsk, Dnipropetrovsk, and Luhansk regions.

6. Emissions from garbage/waste

- Waste from houses and commercial structures destroyed by blast waves or damaged by military vehicles:
  - wooden structures, windows, doors, furniture, household items, personal effects, fences, etc.
  - Trees were cut down to use the wood to build: trenches, dugouts, or other shelters.

Waste from houses and commercial structures destroyed by blast waves or damaged by military vehicles:
- Emissions – 36.8 kt CH₄

18 months of the war:
- Emissions – 36.8 kt CH₄
**Estimated war-related GHG emissions from the first 18 months of the 2022/2023 war in Ukraine**

Emissions that originated from the territory of Ukraine but due to their specificity will likely not be covered by Ukraine's next NIRs to the UNFCCC - or they may be reported in a nontransparent way with high uncertainty.

<table>
<thead>
<tr>
<th>Emission sources</th>
<th>CO₂, Mt</th>
<th>CH₄, kt</th>
<th>N₂O, kt</th>
<th>Total, MtCO₂-eq.</th>
<th>Relative uncertainty (±)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of bombs, missiles, barrel artillery, mines, etc.</td>
<td>0.28</td>
<td>–</td>
<td>–</td>
<td>0.28</td>
<td>+/- 53.9</td>
</tr>
<tr>
<td>Use of petroleum products for military actions</td>
<td>28.5</td>
<td>0.25</td>
<td>0.68</td>
<td>28.7</td>
<td>+/- 40.3</td>
</tr>
<tr>
<td>Fires of petroleum products at petroleum storage depots</td>
<td>5.4</td>
<td>0.21</td>
<td>0.04</td>
<td>5.43</td>
<td>+/- 20.3</td>
</tr>
<tr>
<td>Fires of buildings and infrastructure objects</td>
<td>17.8</td>
<td>5.0</td>
<td>0.73</td>
<td>18.1</td>
<td>+/- 50.5</td>
</tr>
<tr>
<td>Forest fires and fires of agricultural fields</td>
<td>21.1</td>
<td>63.3</td>
<td>3.5</td>
<td>23.8</td>
<td>+/- 42.9</td>
</tr>
<tr>
<td>Emissions from garbage/waste</td>
<td>–</td>
<td>36.8</td>
<td>–</td>
<td>0.92</td>
<td>+/- 68.8</td>
</tr>
<tr>
<td><strong>Total emissions:</strong></td>
<td>73.1</td>
<td>105.6</td>
<td>4.96</td>
<td>77.2</td>
<td>+/- 23.3</td>
</tr>
</tbody>
</table>

\[ \approx \text{Annual total GHG emissions of Austria, Portugal, or Hungary} \]
“Peace time” vs “War time”
First 18 months of the 2022/2023 war in Ukraine:

Conclusions

\[ \Delta = -156.7 \text{ Mt CO}_2\text{-eq.} \]
(18-month period)

\[ \Delta = +77.2 \text{ Mt CO}_2\text{-eq.} \]
(18-month period)

UNFCCC reporting on GHG emissions
IPCC Guidelines
National Inventory Reports (NIRs)

Unaccounted/Unreported in NIRs
(not covered by IPCC Guidelines)

Changes in ‘traditional’ emission sectors
Emission sectors that will be covered by NIR, among others:
- Iron and steel production, non-ferrous metals (-56.3 Mt CO\textsubscript{2}-eq.)
- Public electricity and heat production (-47.7 Mt CO\textsubscript{2}-eq.)
- Road transportation, other transportation (-12.8 Mt CO\textsubscript{2}-eq.)
- Chemical industry (-11.6 Mt CO\textsubscript{2}-eq.)
- Commercial/residential sector (-10.7 Mt CO\textsubscript{2}-eq.)
- Oil and natural gas production (-5.8 Mt CO\textsubscript{2}-eq.)

Additional emissions from military actions
Emission processes that will not be covered by NIR:
- Use of bombs, missiles, artillery, mines, etc. (+0.28 Mt CO\textsubscript{2}-eq.)
- Use of petroleum products for military actions (+28.7 Mt CO\textsubscript{2}-eq.)
- Fires of petroleum storage depots (+5.4 Mt CO\textsubscript{2}-eq.)
- Fires of buildings and infrastructure objects (+18.1 Mt CO\textsubscript{2}-eq.)
- Forest fires and fires of agricultural lands (+23.8 Mt CO\textsubscript{2}-eq.)
- War-related garbage/waste (+0.92 Mt CO\textsubscript{2}-eq.)
Military Emissions Gap Conference 2023

MILITARY AND CONFLICT GHG EMISSIONS: FROM UNDERSTANDING TO MITIGATION

Tuesday 26 September, University of Oxford, and online
The environmental footprint of WWII

Military and Conflict Emissions Conference
From understanding to mitigation
Oxford, 26 September 2023

Ladan Abrari
Doctoral Student | Sustainability Science
LUT University, Finland
WWII: The most destructive war

- Deadliest conflict in human history
- Most expensive war
- The most disastrous for the environment
INTRODUCTION

C-footprint = ton CO₂ (eq) emitted

Bombing of Dresden, 1945

From: BBC
C-FOOTPRINT EMISSION ORIGIN

Fuel/ Transport

From: Wikimedia

Fire/ Bombing

From: History of Yesterday

Resiliency

From: Business Insider

Production

From: War on Rocks

C-footprint sources

A

B

C

D

E
RESEARCH METHODOLOGY

Bottom up

INPUT

History
Military
Resource
Civil
Social

PROCESS

Heuristics

OUTPUT

C-footprint
OUTCOMES AND SPECULATIONS

Outcomes

• C-footprint and climate change impact
• Socio-technical transition
• Societal impact
• Databank and seed

Speculations

• Reference value
• WWII stigma and societal impact
• Political implementations near 2050
ANNUAL CO2 EMISSIONS BY KEY COUNTRIES

Our World in Data
ANNUAL CO2 EMISSIONS BY FUEL

Our World in Data
CO2 EMISSIONS BY FUEL CONSUMPTION IN GERMANY

Includes all motor gasoline, diesel fuel, and aviation fuel.
CO2 EMISSIONS BY OIL CONSUMPTION IN USA

- Total
- Military
- Oil production
ROUGH ESTIMATION OF CO2 EMISSIONS BY FUEL CONSUMPTION FOR OTHER KEY COUNTRIES
TRANSITIONS

- Demographic Changes
- Economic Impact
- Industrial and Technological Advancements
- Environmental Aspects
CHALLENGES

Technical
- Database
- Fuzzy boundaries and contingency
- Biases and variability
- Unknowns

Social costs
- Premature death
- Disability
- Mental health issues
- Talents wasted, dispositioned
- Resiliency

From: Global Social Change
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