Military Emissions Gap Conference 2023

MILITARY AND CONFLICT GHG EMISSIONS: FROM UNDERSTANDING TO MITIGATION

Tuesday 26 September, University of Oxford, and online
Military GHG emissions – status and needs

Linsey Cottrell

Environmental Policy Officer - Conflict and Environment Observatory
CEOBS is a UK charity working to increase the protection of people and ecosystems from the impact of armed conflicts and military activities

www.ceobs.org
Why focus on the military?

• They are huge consumers of **fossil fuels**

• We **know relatively little** about their overall impact on global GHG emissions

• This **needs to change**, with improved data, transparency and reporting
Purpose

• Review of UNFCCC data submitted
• Help understand what is already being reported
• Where are the gaps?
• What is needed?

www.militaryemissions.org
<table>
<thead>
<tr>
<th>Category</th>
<th>Base year</th>
<th>1990</th>
<th>Last Inventory Year (2020)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.A.5 Other (Not specified elsewhere)</td>
<td>551.50</td>
<td>545.08</td>
<td>224.59</td>
</tr>
<tr>
<td>1.A.5.a Stationary</td>
<td>486.61</td>
<td>480.44</td>
<td>202.37</td>
</tr>
<tr>
<td>1.A.5.b Mobile</td>
<td>64.69</td>
<td>64.63</td>
<td>22.21</td>
</tr>
</tbody>
</table>
Key points

- Spending up – US$ 2.42 trillion in 2022
- UNFCCC data submitted in 2023 (2021)
- Annex 1 countries - only 5 reported in line with UNFCCC obligations
- Non Annex 1 countries included those with large military expenditure – e.g. China, India, Saudi Arabia, South Korea, Brazil, Israel
What is the global contribution?

• Estimate – not based on UNFCCC data

• Used ‘active’ military personnel numbers & ‘stationary’ emission

• Ratio of ‘stationary’ to mobile emissions and supply chain multiplier

• 2,750 million tonnes CO₂, 5.5% of global total

https://tinyurl.com/cxp2edw9
If the world's militaries were a country, it would have the fourth highest carbon footprint.
TOTAL GHG EMISSIONS LINKED TO THE MILITARY

1. SOME DATA - FUEL USE
2. LIMITED DATA - ENERGY USE
3. VERY LIMITED DATA - SUPPLY CHAIN
3+ - WARFIGHTING ACTIVITIES

GREENHOUSE GASES
GHG emissions from military fuel and energy use:

- SCOPES
- 1
- 2

GHG emissions from military supply chain and procurement:

- Waste management
- Telecommunications
- Health and welfare
- Construction
- Logistics
- Facility management
- Military technology, equipment and munitions
- Private security
- Maintenance
- Catering
- Office supplies

SCOPE 3

Conflict and Environment Observatory

The Minor Foundation for Major Challenges
**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
Nationally Determined Contributions (NDCs)

- National action plans
- Key to achieving long-term goals
- New NDCs from 2020, then updated every five years
- Successive NDCs need to be ambitious
- Military GHG reductions not in current NDCs

Source: https://www.wri.org/publication/ndc-enhancement-by-2020
Importance of data and targets

• Better understanding of total emissions

• Separate reporting across the MOD’s top-level budget holders

• Setting of consistent milestones or targets
Steps already being taken

• Published NATO methodology:
  - explicitly excludes emissions from NATO-led operations and missions

• Compendium of best practice:
  - annual updates?

• Scope of in-country military emissions reporting:
  - Slovenia, Denmark, and Norway
To conclude....

- Transparency and an improvement in reporting and data is critical
- Need emissions addressed under UNFCCC and in the NDCs
- Improvements possible – reflected already in some in-country reporting
- Reporting improvements needed
- Reduction commitments and target setting needed
- Be curious - check your government’s reporting - [www.militaryemissions.org](http://www.militaryemissions.org)
  - check your government’s NDC - [https://unfccc.int/NDCREG](https://unfccc.int/NDCREG)
Thank you

Linsey Cottrell

Environmental Policy Officer - Conflict and Environment Observatory

www.militaryemissions.org
Military Emissions Gap Conference 2023

MILITARY AND CONFLICT GHG EMISSIONS: FROM UNDERSTANDING TO MITIGATION

Tuesday 26 September, University of Oxford, and online
ENVIRONMENT ASSESSMENT OF WEAPON SYSTEMS WITH A LIFE-CYCLE APPROACH

Carlos Ferreira
José Baranda Ribeiro
ADAI research group capabilities

Provide conditions for the formulation and experimental characterization of energetic materials and expertise in ammunition technology:

• Explosives
  Detonation velocity and pressure; Detonation front curvature; Critical diameter and detonation extinction phenomena; Features of the shock initiation of explosives; Features of crystal reaction kinetics.

• Propellants
  Combustion rates.

• Pyrotechnics
  Initiation devices.

• Ammunition expertise
  Long term collaboration with the Portuguese Armed Forces, NATO-STO AVT Technical groups, and demilitarization companies.
ADAI research group capabilities

Develops and applies tools to enhance the sustainability of products and systems supported by life-cycle thinking. The team provides expertise in:

- Life-cycle management;
- Environmental life-cycle assessment (LCA);
- Life-Cycle Costing (LCC);
- Ecodesign;
- Urban metabolism;
- Circular Economy;
- Other sustainability tools.
Participation in NATO-STO AVT research groups and EDA projects

Main NATO-AVT activities:

- AVT-177 – Munition and propellant disposal and its impact on the environment
- AVT-179 – Design for disposal of present and future munitions and application of greener munition technology
- AVT-277 – Hazard assessment of exposure to ammunition-related constituents and combustion products
- AVT-293 – Effect of environmental regulation on energetic systems and the management of critical munitions materials and capability

EDA Projects:

- ERM – Environmental responsible munitions (2011-2015);
- PREMIUM - Prediction models for implementation of munition health management (2021-2025)
LCA application for military systems

Demilitarization of military ammunition with incineration in a static kiln

LCA application for military systems

Demilitarization of military ammunition

- Primary data was used from the demilitarization company

LCA application for military systems

Demilitarization of military ammunition

- Impacts associated with the incineration in a static kiln and flue gas treatment processes.

LCA application for military systems

Downcycling of energetic material from military ammunition via incorporation into civil explosives

A circular economy approach

Primary data provided from a company that produces civil explosives

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonium Nitrate</td>
<td>1.06 kg</td>
</tr>
<tr>
<td>Water</td>
<td>0.16 kg</td>
</tr>
<tr>
<td>XPS</td>
<td>0.03 kg</td>
</tr>
<tr>
<td>Mineral oil</td>
<td>0.13 kg</td>
</tr>
<tr>
<td>Polycarboxylate</td>
<td>0.07 kg</td>
</tr>
<tr>
<td>Packing</td>
<td></td>
</tr>
<tr>
<td>Polyethylene (includes packing)</td>
<td>1.50 kg</td>
</tr>
<tr>
<td>Ashes</td>
<td>0.002 kg</td>
</tr>
<tr>
<td>Inert material</td>
<td>0.003 kg</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Energy requirement</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>0.11 kWh</td>
</tr>
<tr>
<td>Naphtha</td>
<td>0.01 kg</td>
</tr>
</tbody>
</table>


Table 1

Table 2

26th September
Military Emissions Gap Conference
LCA application for military systems

Comparison between three methods of ammunition disposal: open detonation, incineration in a static kiln, recycling of energetic material.

The next step was to assess the impacts from the other life-cycle phases of ammunition (production and use)

The main motivation to carry out this studies:

- Large amount of munitions used in training – contamination of military ranges
- Production have a significant impact that needs to be considered (e.g. carbon footprint)
- Impacts over human health – (e.g. inhalation of fumes from soldiers)

Collaboration in EDA project and NATO groups allowed to obtain information in order to assess the impacts of large and small calibers.
LCA application for military systems

Creation of databases:

- The creation of the life-cycle inventory is one of the most important steps of the LCA studies - Compilation of data regarding energy, materials, products, transport, co-products, etc.

- EcolInvent has a set of databases available for different types of raw materials, chemicals, energy sources, etc. However, energetic materials and other chemicals are missing in those databases.

- Experience in creating databases for different types of materials, products and activities:

  - Real data surveys for compilation of data from industry
  - Literature data
  - Estimations following recommendations from EcolInvent

Hierarchy of data compilation
LCA application for military systems

Creation of databases:

• The inventories created are based on a complementary combination of the three approaches based on the type of data that is available.

• The real data obtained from the industry for the energetic material production is very scarce.

• Most of the data used in the compilation of information is based on literature sources, such as scientific papers, books, patents, sustainability reports, or companies’ websites.
LCA application for military systems

Creation of databases:

Third approach: life-cycle inventories for production are created based on the procedure developed by Hischier et al. (2005), as implemented in other LCA studies.

This approach suggests:

- Stoichiometric chemical equation to account for raw materials consumption (with an efficiency level of 95%);
- Consumption of electricity and heat based on average values (0.33 kWh and 2 MJ per kg of product - Gendorf, 2000);
- 0.2% of the volatile input materials are emitted into the air.
LCA application for military systems

AVT study – production and use of large caliber (155 mm caliber ammunition)

- Production presents a higher contribution to the environment impact categories;
- Use phase has a higher contribution to the toxicological impact categories;
- Exception for triple base powder production for ecotoxicity: emissions of insecticides into the soil (Profenofos, Cyfluthrin, Chlorpyrifos, and Aldicarb) used in the cultivation of cotton - nitrocellulose production.
EDA project - Ecodesign of small calibre ammunition

4 different small caliber munition:

- Steel-lead projectile
  - Lead primer #1
  - Non-lead primer #2
- Composite projectile
  - Lead primer #3
  - Non-lead primer #4

LCA application for military systems

EDA project - Ecodesign of small calibre ammunition

Primary data regarding the main components of the ammunition and the emissions

<table>
<thead>
<tr>
<th>#1</th>
<th>Constitution</th>
<th>Amount (kg)</th>
<th>#2</th>
<th>Constitution</th>
<th>Amount (kg)</th>
<th>#3</th>
<th>Constitution</th>
<th>Amount (kg)</th>
<th>#4</th>
<th>Constitution</th>
<th>Amount (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cartridge</td>
<td>Brass</td>
<td>4.9E-03</td>
<td>Brass</td>
<td>4.9E-03</td>
<td>Brass</td>
<td>4.9E-03</td>
<td>Brass</td>
<td>4.9E-03</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Steel</td>
<td>3.9E-03</td>
<td>Steel</td>
<td>3.9E-03</td>
<td>Nylon</td>
<td>4.1E-03</td>
<td>Nylon</td>
<td>4.1E-03</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lead</td>
<td>6.1E-03</td>
<td>Lead</td>
<td>6.1E-03</td>
<td>Copper</td>
<td>1.0E-03</td>
<td>Copper</td>
<td>1.0E-03</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Antimony powder</td>
<td>9.5E-05</td>
<td>Antimony powder</td>
<td>9.5E-05</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primer</td>
<td>Brass</td>
<td>2.4E-04</td>
<td>Brass</td>
<td>2.4E-04</td>
<td>Brass</td>
<td>2.4E-04</td>
<td>Brass</td>
<td>2.4E-04</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>TNR-Pb</td>
<td>1.0E-05</td>
<td>TNR-Pb</td>
<td>1.0E-05</td>
<td>Tetryazine</td>
<td>1.3E-06</td>
<td>Tetryazine</td>
<td>1.3E-06</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Tetrazyne</td>
<td>1.3E-06</td>
<td>Tetrazyne</td>
<td>1.3E-06</td>
<td>Barium nitrate</td>
<td>4.9E-06</td>
<td>Barium nitrate</td>
<td>4.9E-06</td>
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<tr>
<td></td>
<td>Barium nitrate</td>
<td>4.9E-06</td>
<td></td>
<td></td>
<td>Antimony sulphide</td>
<td>1.3E-06</td>
<td>Antimony sulphide</td>
<td>1.3E-06</td>
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<tr>
<td></td>
<td>Antimony sulphide</td>
<td>1.3E-06</td>
<td></td>
<td></td>
<td>Lead dioxide</td>
<td>3.7E-06</td>
<td>Lead dioxide</td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lead dioxide</td>
<td>1.3E-06</td>
<td></td>
<td></td>
<td>Calcium silicone</td>
<td>1.3E-06</td>
<td>Calcium silicone</td>
<td>1.3E-06</td>
<td></td>
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<tr>
<td></td>
<td>Calcium silicone</td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Cardboard</td>
<td>3.2E-04</td>
<td>Cardboard</td>
<td>3.2E-04</td>
<td>Cardboard</td>
<td>3.2E-04</td>
<td>Cardboard</td>
<td>3.2E-04</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total weight</td>
<td></td>
<td>1.6E-02</td>
<td></td>
<td></td>
<td>1.1E-02</td>
<td></td>
<td></td>
<td>1.1E-02</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Substance</th>
<th>Emissions (mg/bullet)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>#1</td>
</tr>
<tr>
<td>CO</td>
<td>198.65</td>
</tr>
<tr>
<td>CO₂</td>
<td>101.79</td>
</tr>
<tr>
<td>NO</td>
<td>3.80</td>
</tr>
<tr>
<td>NO₂</td>
<td>0.64</td>
</tr>
<tr>
<td>NH₃</td>
<td>3.10</td>
</tr>
<tr>
<td>HCN</td>
<td>1.77</td>
</tr>
<tr>
<td>CH₄</td>
<td>1.10</td>
</tr>
<tr>
<td>Pb</td>
<td>3.14</td>
</tr>
<tr>
<td>Cu</td>
<td>0.55</td>
</tr>
<tr>
<td>Zn</td>
<td>0.12</td>
</tr>
<tr>
<td>Sb</td>
<td>0.37</td>
</tr>
</tbody>
</table>


Electricity 0.046 kWh/bullet
Natural gas 0.240 MJ/bullet
Water 2.042 kg/bullet
LCA application for military systems

EDA project - Ecodesign of small calibre ammunition

LCA application for military systems

EDA project - Ecodesign of small calibre ammunition

Production Phase

- #1: steel/lead
- #2: steel/non-lead
- #3: composite/lead
- #4: composite/non-lead

Use Phase

- #1: steel/lead
- #2: steel/non-lead

Conclusions

Contribution in the last 12 years for the improvement of the environment profile of military systems:

• Creation of inventories (production, use) for 20 energetic materials;
• Ecodesign of ammunition and their components (energetic and non-energetic);
• Identification of environmental hot-spots associated to ammunition;
• Development of greener “designed for disposal” ammunitions;
• Comparison of disposal techniques;
• Assessment of the degree of contamination of shooting ranges;
• Assessment of impacts over human health (in combination with REACH regulation).
Conclusions

Ongoing work:

- Assessment of indoor impacts;
- Development of a tool to assist the environment management of shooting ranges;
- Creation of a database for energetic materials (production and use) and weapon systems.

In the scope of AVT-SP-004 (NATO) and Incubation Forum from EDA.
THANK YOU!

Carlos Ferreira: carlos.ferreira@dem.uc.pt
José Baranda Ribeiro: jose.baranda@dem.uc.pt

26TH SEPTEMBER, OXFORD, UK
Military Emissions Gap Conference 2023

MILITARY AND CONFLICT GHG EMISSIONS: FROM UNDERSTANDING TO MITIGATION

Tuesday 26 September, University of Oxford, and online
Life cycle GHG emissions in the Norwegian defence sector

Magnus Sparrevik
Senior advisor Norwegian Defence Estates Agency
Adjunct professor NTNU
History

Master thesis in 2017 - inspired of the SETAC UNEP Framework of organizational LCA.
Compilation and evaluation of the inputs and outputs and the environmental impacts of a product system throughout its life cycle

National account

Emission factors

Activity specific emissions

CO₂, CH₄, N₂O, HFCs, PFCs, SF₆, NF₃
Total emissions from Norwegian consumption 70.8 mill tonnes

Norwegian defence sector 0.8 mill tonnes

Public, excluding defence 10.4 mill tonnes

Private investments 15.6 mill tonnes

Household consumption 44.0 mill tonnes
Limitations

- No strategic military investments included
- Few LCA processes exist for military equipment
- The characterization factors for economic LCA are generic and not suitable for performance evaluation
Today

Publicly accessible GHG account includes scope 1-3. Both process and economic data are used.

Forsvarkssektorens miljø- og klimaregnskap for 2022 (ffi.no)

https://doi.org/10.1016/j.jclepro.2019.119196

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Military Emissions Gap Conference 2023

MILITARY AND CONFLICT GHG EMISSIONS: FROM UNDERSTANDING TO MITIGATION

Tuesday 26 September, University of Oxford, and online
‘Hidden’ carbon footprints: An examination of the US military’s use of concrete walls in Iraq

Military conflict emissions
Oxford conference Sept. 26, 2023

Dr Reuben Larbi
Dr Benjamin Neimark, Dr Kirsti Ashworth & Oliver Belcher
Funding made possible by the UKRI-ESRC Concrete Impacts Project
https://www.concreteimpacts.org/
Introduction

• War and military intervention have damaging impacts on environment and humans
  – casualties, displacements, destruction to property and landscape, water pollution ...

• The carbon footprint remains a major gap:
  – 2019 EU military = 24.8 million tCO2e, ~ emissions from 14 million average sized cars
    (Parkinson and Cottrell 2021)
  – US military would be 47th largest carbon emitter [country] based on fuel usage alone
    (Neimark et al. 2020)
  – Socio-ecological impacts of military operations remain poorly investigated
Objective: the carbon footprint from concrete walls used in the second Iraq war (2003-2008).
Why worry about the use of concrete?

- Concrete barriers are significant component of modern warfare and conflict control – Afghanistan, West Bank, Iraq
- Global consumption ~ 30 million tonnes annually
- Carbon intensive-> up to 8% of total global GHG
- 2nd most consumed material
Socio-economic Impacts of concrete walls

- Segregated communities- Shiite and Sunni
- Altered urban fabric
- Vehicular traffic
- Restricted movements & access to essential services
- Restricted emergency services
- Increased economic hardships
- Abated violence
Materials and Methods (1)

- Neighbourhood and blast protection walls
- Data deficit - wall lengths, barrier types, etc
- Fiji ImageJ to extract the length of walls from info graph (Gulf project, Columbia University)
- Constituents of concrete from standard M20 mixture - (PCA, 2007)

\[
\text{Embodied carbon (EC)} = \sum_{k=0}^{n} \text{Inputs} \times \text{Emission Factors}
\]

Emissions factors are from the Inventory of Carbon and Energy, 2019

Total length of walls = 412 km
Methods and Materials (2)

• **Estimation of total embodied carbon (EC)**
  - Three walling scenarios

\[
Total \ EC = \sum_{k=0}^{n} (EC \ of \ barrier \ type) \times No. \ of \ barriers
\]

• **Quantification of uncertainty**
  - Sources: Activity data & Emission factors
  - Method: Monte Carlo Simulation with 100,000 iterations
  - Mean and standard deviation computed
Results

CO2 emissions inventory to produce 1m³ of concrete

<table>
<thead>
<tr>
<th>Constituents/process</th>
<th>Water</th>
<th>Sand</th>
<th>Crushed stones</th>
<th>Pre-casting</th>
<th>Steel</th>
<th>Portland cement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Embodied carbon (kgCO2e)</td>
<td>10</td>
<td>50</td>
<td>150</td>
<td>200</td>
<td>250</td>
<td></td>
</tr>
</tbody>
</table>

Type of concrete barrier and embodied carbon

<table>
<thead>
<tr>
<th>Barrier type</th>
<th>Jersey</th>
<th>Texas</th>
<th>Alaska</th>
</tr>
</thead>
<tbody>
<tr>
<td>Image (not drawn to scale)</td>
<td><img src="image1" alt="Image" /></td>
<td><img src="image2" alt="Image" /></td>
<td><img src="image3" alt="Image" /></td>
</tr>
<tr>
<td>Volume of concrete (m³)</td>
<td>0.96</td>
<td>3.02</td>
<td>4.78</td>
</tr>
<tr>
<td>Embodied carbon (kgCO2e/m³)</td>
<td>392.10</td>
<td>1233.49</td>
<td>1952.34</td>
</tr>
</tbody>
</table>
## Results (2)---- Total Embodied Carbon

<table>
<thead>
<tr>
<th>Walling Scenario</th>
<th>Length of barrier (km)</th>
<th>Number of sections of barrier</th>
<th>Total EM (kt CO$_2$e)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Jersey</td>
<td>Texas</td>
<td>Alaska</td>
</tr>
<tr>
<td>S1</td>
<td>0</td>
<td>412</td>
<td>0</td>
</tr>
<tr>
<td>S2</td>
<td>0</td>
<td>412</td>
<td>0</td>
</tr>
<tr>
<td>S3</td>
<td>63</td>
<td>286</td>
<td>63</td>
</tr>
</tbody>
</table>

**S1**: All blast and neighbourhood walls are formed of Texas barriers  
**S2**: All blast and neighbourhood walls are Texas barriers but blast walls are double layered  
**S3**: All blast walls are Texas. Neighbourhood walls are an equal mix of single layer Jersey, Texas and Alaska
Discussion and conclusion

• We estimated 412 km of concrete T walls in Baghdad (2003-2008)
  – Using LCA -> 0.2 million tonnes of CO2e
  – ~43,000 typical passenger vehicles on the road for a year
  – ~ total annual emissions of a small island nation

• World Militaries emit 1%-5% of global GHG ~ Aviation & shipping industries

• Largely spared from emission reporting:
  – absence of accountability and hence reliable data
  – FOIA requests difficult to access data

• UNFCCC should develop a framework for military emission reporting including war time
Our Actions: Get the Science Right

- More research is needed
- **Work in progress**: a review paper on military emission gap
Our Actions: Get the word out

Panel discussion and media briefing on MEG at COP26
Adding to what we already know/don’t know

THE MILITARY EMISSIONS GAP

DATA · PROBLEM · SOLUTION · RESOURCES · ABOUT

View your government’s military emissions data

40 industrialised countries spent $1.2tn on their militaries in 2020.

Only 5 reported their emissions in line with UNFCCC guidelines.

15 countries, including China, India, Saudi Arabia, South Korea, Brazil, Iran and Pakistan spent $510 bn on their militaries in 2020.

None reported any disaggregated data on their military emissions to the UNFCCC.
Thank You!

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Military Emissions Gap Conference 2023

MILITARY AND CONFLICT GHG EMISSIONS: FROM UNDERSTANDING TO MITIGATION

Tuesday 26 September, University of Oxford, and online