



# Overview of the Department of Defense (DoD) Sustainability Analysis Dataset

March 25, 2015

# Outline

## 1. Data Documentation Notes

- A. Life Cycle Inventory (Technosphere and Activity Flows) – A Matrix
  - I. Economic Flows by Economic Flows (DoD EnvIO)
  - II. Economic Flows by Energy Flows
  - III. Economic Flows by Transportation Flows
  - IV. Accounting for Inflation
- B. Life Cycle Inventory (Environmental Flows) – B Matrix
- C. Life Cycle Impact Characterization and Valuation – C Matrix

## 2. DoD EnvIO Summary Results

- A. Unnormalized DoD EnvIO Impact-Per-Spend Valuation Results
- B. Normalized DoD EnvIO Impact-Per-Spend Valuation Results

# 1. Data Documentation Notes

## A. Life Cycle Inventory (Technosphere and Activity Flows) – A Matrix

# A Matrix: Overview

- **Summary:** Also known as the Technological Matrix, the A Matrix records each activity's (e.g., economic output, energy use, and transportation) direct input requirements across all available technosphere flows (e.g., commodity input) occurring throughout the economy.
- **File Name:** Final\_A\_Matrix.xlsb
- **Matrix Dimensions:**
  - **Rows [i]:** 787 technosphere flows (inputs)
  - **Columns [j]:** 787 activity flows (outputs)
  - **Cells [i,j]:** Amount of technosphere flow [i] required to produce one unit of activity [j], as recorded in units of that activity's reference flow
- **Notes:**
  - The A Matrix developed for DoD Sustainability Analyses is a hybridized dataset composing a technological matrix from a traditional economic input-output model and adjoining vectors capturing activity data in units of physical flows.

# A Matrix: Economic Flows

- **Summary:** Based on 2007 data from the Bureau of Economic Analysis (BEA), the DoD Environmental Input-Output (DoD EnvIO) captures all input and output economic flows across the U.S. economy, as well as U.S. Imports modeled as if they were made in the U.S. This matrix of economic flows is used to calculate the amount of input required from direct suppliers to produce one USD2007 of output in a specified industry sector.
- **Matrix Attributes:**
  - **Rows [i]:** 391 technosphere flows (supplying industry)
  - **Columns [j]:** 391 activities (producing industry)
  - **Cells [i,j]:** Industry j's total direct spend (USD2007) in industry i per dollar output for industry j (USD2007)
- **Relevant Master List File Name(s):**
  - MasterLists\_TechnosphereFlows\_2007.xlsb
  - MasterLists\_Activities\_2007.xlsb
- **Notes:**
  - Combined BEA's use and make tables after redefinitions
  - Combined 3 BEA electricity sectors into one electricity sector,
  - Derived direct and total requirements matrices following BEA's methodology for commodity-by-commodity, commodity-by-industry, and industry-by-industry.

# A Matrix: Energy Flows

- **Summary:** Added as data vectors to the core DoD EnvIO A Matrix, a set of custom, pre-defined energy flows were created for the DoD to capture the full life cycle use of energy commodities (e.g., oil & gas products, electricity, and coal), including energy use in the DoD's supply chain and downstream operations.
- **Matrix Attributes:**
  - **Rows [i]:** 342 energy technosphere flows (energy commodity inputs)
  - **Columns [j]:** 342 activities (energy use, i.e. stationary & mobile combustion and electricity consumption)
  - **Cells [i,j]:** Total amount of energy input [i] required for one unit of activity [j], as measured by that activity's reference unit
- **Relevant Master List File Name(s):**
  - MasterLists\_TechnosphereFlows\_2007.xlsb
  - MasterLists\_Activities\_2007.xlsb
- **Notes:**
  - Multiple sources were used to create data for energy flows (see slide 8)

# A Matrix: Transportation Flows

- **Summary:** Added as data vectors to the core DoD EnvIO A Matrix, a set of pre-defined transportation flows were created for the DoD to track the transport of commodities in the DoD supply chain, as well as provide estimates for downstream operations.
- **Matrix Attributes:**
  - **Rows [i]:** 54 transportation technosphere flows (transportation input)
  - **Columns [j]:** 54 activities (transportation use)
  - **Cells [i,j]:** Total amount of transportation input [i] required for one unit of activity [j], as measured by that activity's reference unit
- **Relevant Master List File Name(s):**
  - MasterLists\_TechnosphereFlows\_2007.xlsb
  - MasterLists\_Activities\_2007.xlsb
- **Notes:**
  - Multiple sources were used to create data for transportation flows (see slide 8)

# A Matrix: Sources

Source	Relevant Flows	Link
2007 BEA Input-Output Accounts Data (Total Requirements)	Economic	<a href="http://www.bea.gov/industry/io_annual.htm">http://www.bea.gov/industry/io_annual.htm</a>
US-EPA AP-42 (Chapters 1.1, 1.3-3.4, 1.5, 1.6)	Energy (Stationary & Mobile Combustion)	<a href="http://www.epa.gov/ttnchie1/ap42/">http://www.epa.gov/ttnchie1/ap42/</a>
US-EPA eGRID (9th edition)	Energy (U.S. Electricity Use)	<a href="http://www.epa.gov/cleanenergy/energy-resources/egrid/">http://www.epa.gov/cleanenergy/energy-resources/egrid/</a>
EMEP/EEA 2009 Air Pollutant Emission Inventory	Energy (Stationary & Mobile Combustion)	<a href="http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009">http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009</a>
EMEP/EEA 2013 Air Pollutant Emission Inventory Guidebook (Section 1.A.5.b)	Energy (Stationary & Mobile Combustion)	<a href="http://www.eea.europa.eu/publications/emep-eea-guidebook-2013">http://www.eea.europa.eu/publications/emep-eea-guidebook-2013</a>
IEA Country Electricity/Heat Statistics	Energy (Non-U.S. Electricity Use)	<a href="http://www.iea.org/statistics/topics/Electricity/">http://www.iea.org/statistics/topics/Electricity/</a>
EIA Form 1605	Energy (U.S. & Non-U.S. Electricity Use)	<a href="http://www.eia.gov/survey/form/eia_1605/1605text.html">http://www.eia.gov/survey/form/eia_1605/1605text.html</a>
GREET 2013	Energy (Mobile Combustion) Transportation	<a href="https://greet.es.anl.gov/greet/setup2013/">https://greet.es.anl.gov/greet/setup2013/</a>
EPA MOVES 2010 (a & b)	Energy (Mobile Combustion) Transportation	<a href="http://www.epa.gov/otaq/models/moves/">http://www.epa.gov/otaq/models/moves/</a>

# A Matrix: Recommended Indices for Industry-Specific Price Adjustments

All technosphere flows are connected to monetary flows, which must be adjusted to USD2007 to ensure accurate calculations for impact assessment. Recommended methods for inflation adjustment include:

## •Purchaser Price Index (PPI)

- **Source:** Bureau of Labor Statistics (BLS) Industry and Commodity PPI Data
- **Link:** <http://www.bls.gov/ppi/data.htm>

NOTE: An indexed PPI dataset is included in the DoD Sustainability Analysis Dataset, covering:

- Industry-specific inflation from 2002 to 2014 (note: 2015 data uses 2014 data as a placeholder)
- Commodity-specific inflation from 2002 to 2014 (note: 2015 data uses 2014 data as a placeholder)
- Economy-wide inflation from 1913 to 2014 (note: 2015 data uses 2014 data as a placeholder)

## •Gross Output (GO) price indices

- **Source:** Bureau of Economic Analysis (BEA) National Accounts
  - Gross Domestic Product (GDP) by Industry Data
- **Link:** [http://www.bea.gov/industry/gdpbyind\\_data.htm](http://www.bea.gov/industry/gdpbyind_data.htm)

# 1. Data Documentation Notes

B. Life Cycle Inventory (Environmental Flows) – B Matrix

# B Matrix: Overview

- **Summary:** The B Matrix allocates 10,594 unique combinations of environmental flows, compartments, and locations to each activity recorded in the A Matrix. In this model, environmental flows are resource inputs and resulting releases occurring within 136 unique environmental compartments. As allocated, this model can track environmental flows embedded in procured products and services and associated with downstream activities.
- **File Name:** Final\_B\_Matrix.xlsb
- **Matrix Dimensions:**
  - **Rows [i]:** 10,594 environmental flows, organized by environmental compartment and location
  - **Columns [j]:** 787 activity flows
  - **Cells [i,j]:** Amount of environmental flow [i] allocated to one unit of activity [j], as recorded in units of that activity's reference flow
- **Notes:**
  - Environmental flows are grouped into three broad categories: (1) natural resources, (2) releases, and (3) labor. Data sources and general notes are covered in slides 12-17.

# B Matrix: Data Sources (Natural Resources)

Environmental Flow Category	Data Sources	Links
Water use	USGS Circular 1405 USGS Circular 1200 Blackhurst et al., Environ. Sci. Technol., 2010, 44 (6), pp 2126–2130 BEA 2007 Benchmark Accounts	<a href="http://pubs.usgs.gov/circ/1405/">http://pubs.usgs.gov/circ/1405/</a> <a href="http://pubs.er.usgs.gov/publication/cir1200">http://pubs.er.usgs.gov/publication/cir1200</a> <a href="http://pubs.acs.org/doi/abs/10.1021/es903147k">http://pubs.acs.org/doi/abs/10.1021/es903147k</a> <a href="http://www.bea.gov/industry/gdpbyind_data.htm">http://www.bea.gov/industry/gdpbyind_data.htm</a>
Fossil Fuel use	EIA Fossil Fuel Production (2007)	<a href="http://www.eia.gov/beta/MER/?tbl=T01.02#/?f=A&amp;start=1949&amp;end=2014&amp;charted=1-2-3-4-6-13">http://www.eia.gov/beta/MER/?tbl=T01.02#/?f=A&amp;start=1949&amp;end=2014&amp;charted=1-2-3-4-6-13</a>
Mineral use	USGS Mineral Commodities Yearbook (2009)	<a href="http://minerals.usgs.gov/minerals/pubs/myb.html">http://minerals.usgs.gov/minerals/pubs/myb.html</a>
Land use	USDA Agriculture Census (2007) USDA Major Uses of Land in the United States, 2007 Costello et al., Environ. Sci. Technol., 2011, 45 (11), pp 4937–4943	<a href="http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_1_US/st99_1_008_008.pdf">http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_1_US/st99_1_008_008.pdf</a> <a href="http://www.ers.usda.gov/media/188404/eib89_2_.pdf">http://www.ers.usda.gov/media/188404/eib89_2_.pdf</a> <a href="http://pubs.acs.org/doi/abs/10.1021/es104245j">http://pubs.acs.org/doi/abs/10.1021/es104245j</a>

# B Matrix: Data Sources (Releases)

Environmental Flow Category	Data Sources	Links
GHG Emissions	<p><b>For DoD EnvIO</b>            US EPA 2008 Greenhouse Gas Inventory            US EIA Manufacturing Energy Consumption Survey</p> <p><b>For Energy and Transportation Activities</b>            US EPA AP-42 (Chapters 1.1, 1.3-3.4, 1.5, 1.6)            US EPA eGRID (9th edition)            EMEP/EEA 2009 Air Pollutant Emission Inventory Guidebook            EMEP/EEA 2013 Air Pollutant Emission Inventory Guidebook            IEA Country Electricity/Heat Statistics            EIA Form 1605            GREET 2013            EPA MOVES 2010 (a &amp; b)</p>	<p><b>For DoD EnvIO</b>  <a href="http://www.epa.gov/climatechange/ghgemissions/userinventoryreport.html">http://www.epa.gov/climatechange/ghgemissions/userinventoryreport.html</a>  <a href="http://www.eia.gov/consumption/manufacturing/">http://www.eia.gov/consumption/manufacturing/</a></p> <p><b>For Energy and Transportation Activities</b>  <a href="http://www.epa.gov/ttnchie1/ap42/">http://www.epa.gov/ttnchie1/ap42/</a>  <a href="http://www.epa.gov/cleanenergy/energy-resources/egrid/">http://www.epa.gov/cleanenergy/energy-resources/egrid/</a>  <a href="http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009">http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009</a>  <a href="http://www.eea.europa.eu/publications/emep-eea-guidebook-2013">http://www.eea.europa.eu/publications/emep-eea-guidebook-2013</a>  <a href="http://www.iea.org/statistics/topics/Electricity/">http://www.iea.org/statistics/topics/Electricity/</a>  <a href="http://www.eia.gov/survey/form/eia_1605/1605text.html">http://www.eia.gov/survey/form/eia_1605/1605text.html</a>  <a href="https://greet.es.anl.gov/greet/setup2013/">https://greet.es.anl.gov/greet/setup2013/</a>  <a href="http://www.epa.gov/otaq/models/moves/">http://www.epa.gov/otaq/models/moves/</a></p>
Non-GHG Emissions to Air	<p><b>For DoD EnvIO</b>            US EPA 2007 Toxic Release Inventory (TRI)            US EPA 2008 National Emissions Inventory (NEI): Point Sources, Non-Point Sources, On-Road Source, an On-Road Sources</p> <p><b>For Energy and Transportation Activities</b>            US-EPA AP-42 (Chapters 1.1, 1.3-3.4, 1.5, 1.6)            US-EPA eGRID (9th edition)            EMEP/EEA 2009 Air Pollutant Emission Inventory Guidebook            EMEP/EEA 2013 Air Pollutant Emission Inventory Guidebook            IEA Country Electricity/Heat Statistics            EIA Form 1605            GREET 2013            EPA MOVES 2010 (a &amp; b)</p>	<p><b>For DoD EnvIO</b>  <a href="http://www2.epa.gov/toxics-release-inventory-tri-program/tri-basic-data-files-calendar-years-1987-2013">http://www2.epa.gov/toxics-release-inventory-tri-program/tri-basic-data-files-calendar-years-1987-2013</a>  <a href="http://www.epa.gov/ttn/chief/net/2008inventory.html">http://www.epa.gov/ttn/chief/net/2008inventory.html</a></p> <p><b>For Energy and Transportation Activities</b>  <a href="http://www.epa.gov/ttnchie1/ap42/">http://www.epa.gov/ttnchie1/ap42/</a>  <a href="http://www.epa.gov/cleanenergy/energy-resources/egrid/">http://www.epa.gov/cleanenergy/energy-resources/egrid/</a>  <a href="http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009">http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009</a>  <a href="http://www.eea.europa.eu/publications/emep-eea-guidebook-2013">http://www.eea.europa.eu/publications/emep-eea-guidebook-2013</a>  <a href="http://www.iea.org/statistics/topics/Electricity/">http://www.iea.org/statistics/topics/Electricity/</a>  <a href="http://www.eia.gov/survey/form/eia_1605/1605text.html">http://www.eia.gov/survey/form/eia_1605/1605text.html</a>  <a href="https://greet.es.anl.gov/greet/setup2013/">https://greet.es.anl.gov/greet/setup2013/</a>  <a href="http://www.epa.gov/otaq/models/moves/">http://www.epa.gov/otaq/models/moves/</a></p>
Emissions to Water	US EPA 2007 Toxic Release Inventory (TRI)	<a href="http://www2.epa.gov/toxics-release-inventory-tri-program/tri-basic-data-files-calendar-years-1987-2013">http://www2.epa.gov/toxics-release-inventory-tri-program/tri-basic-data-files-calendar-years-1987-2013</a>
Emissions to Soil	US EPA 2007 Toxic Release Inventory (TRI)	<a href="http://www2.epa.gov/toxics-release-inventory-tri-program/tri-basic-data-files-calendar-years-1987-2013">http://www2.epa.gov/toxics-release-inventory-tri-program/tri-basic-data-files-calendar-years-1987-2013</a>
Pesticides	USDA National Agricultural Statistics Service (NASS), Agricultural Chemical Use Program (2007)	<a href="http://www.nass.usda.gov/Surveys/Guide_to_NASS_Surveys/Chemical_Use/">http://www.nass.usda.gov/Surveys/Guide_to_NASS_Surveys/Chemical_Use/</a> <a href="http://quickstats.nass.usda.gov/">http://quickstats.nass.usda.gov/</a>
Agricultural Nutrient Runoff	USDA Natural Resource Conservation Service (NRCS), Conservation Effects Assessment Project (CEAP) (2007) EPA Science Advisory Board (SAB) U.S. Greenhouse Gas Inventory Reports (2007)	<a href="http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/ceap/pub/">http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/ceap/pub/</a> <a href="http://yosemite.epa.gov/sab/sabproduct.nsf/WebBOARD/INCSupplemental?OpenDocument">http://yosemite.epa.gov/sab/sabproduct.nsf/WebBOARD/INCSupplemental?OpenDocument</a> <a href="http://www.epa.gov/climatechange/ghgemissions/userinventoryreport.html">http://www.epa.gov/climatechange/ghgemissions/userinventoryreport.html</a>

# B Matrix: Data Sources (Labor)

Environmental Flow Category	Data Sources	Links
Employment	BLS Current Employment Statistics (CES) Database	<a href="http://www.bls.gov/ces/data.htm">http://www.bls.gov/ces/data.htm</a>
Worker Health, Fatal Incidents	BLS Census of Fatal Occupational Injuries (CFOI) 2003-2010	<a href="http://download.bls.gov/pub/time.series/fi/">http://download.bls.gov/pub/time.series/fi/</a>
Worker Health, Disability Incidents	BLS Survey of Occupational Injuries and Illnesses (SOII) 2003-2010	<a href="http://download.bls.gov/pub/time.series/ch/">http://download.bls.gov/pub/time.series/ch/</a>

# B Matrix: Notes (Natural Resources)

Environmental Flow Category	Notes
Water use	<p><b>For DoD EnvIO</b></p> <ul style="list-style-type: none"> <li>•Water allocation closely methods outlined in Blackhurst et al. (2010), Environ. Sci. Technol., 2010, 44 (6), pp 2126–2130.</li> <li>•The water data vector relies on 1995 and 2010 survey data reported by the US Geological Survey (USGS). USGS stopped surveying for consumptive use in 1995, so this is last year available for consumptive use. It is assumed that the consumptive use fraction from 1995 (consumptive use/withdrawal) can be applied to withdrawal data from 2010.</li> <li>•Water flow values per USD2010 were normalized USD2007 using Gross Output (GO) price indices (see slide 9).</li> <li>•Most water use categories were manually matched to IO sectors. Domestic supply matched 100% to IO sector 221300. Industrial self-supplied water use matched by Canadian water use survey following Blackhurst et al (2010). Agricultural irrigation water use was matched to specific crops using data from the USDA Farm and Ranch Irrigation Survey (FRIS).</li> <li>•It is assumed that all ground water withdrawals not consumed are returned to rivers.</li> </ul>
Fossil Fuel use	<p><b>For DoD EnvIO</b></p> <ul style="list-style-type: none"> <li>•Coal production was manually allocated to coal mining IO sector.</li> <li>•Oil, gas, and liquid natural gas production was manually allocated to the oil &amp; gas extraction IO sector.</li> </ul> <p><b>For Energy and Transportation Activities</b></p> <ul style="list-style-type: none"> <li>•Fossil energy flows were collected from and used as reported by outside sources, as documented on slide 13.</li> </ul>
Mineral use	<p><b>For DoD EnvIO</b></p> <ul style="list-style-type: none"> <li>•Mineral production, as reported by the USGS Mineral Yearbooks, of various minerals were manually allocated to the appropriate mining IO sector.</li> </ul>
Land use	<p><b>For DoD EnvIO</b></p> <ul style="list-style-type: none"> <li>•Multiple sources were consulted which all have slightly different definitions and estimates of land use.             <ul style="list-style-type: none"> <li>○ Data for cropland was provided by the 2007 Census of Agriculture. This data was provided according to NAICS codes and then crosswalked to IO sector codes.</li> <li>○ Data for agricultural grazing, forestry, and transport land use classifications were provided by the USDA Major Uses of Land in the United States, 2007 publication. Such data were confirmed with estimates performed by Costello et al. This data was manually allocated to IO sectors.</li> </ul> </li> </ul>

# B Matrix: Notes (Releases)

Environmental Flow Category	Notes
GHG Emissions	<p>All GHG emissions sources follow the International Panel on Climate Change (IPCC) 2006 guidelines for GHG Inventories.</p> <p><b>For DoD EnvIO</b></p> <ul style="list-style-type: none"> <li>•Source categories allocated manually to IO sectors using a variety of methods.</li> </ul> <p><b>For Energy and Transportation Activities</b></p> <ul style="list-style-type: none"> <li>•Emissions for energy and transportation activities were collected from and used as reported by outside sources, as documented on slide 13. Emissions from mobile combustion were adjusted to provide gross estimates that reflect military platforms.</li> </ul>
Non-GHG Emissions to Air	<p><b>For DoD EnvIO</b></p> <ul style="list-style-type: none"> <li>•TRI and NEI point source emissions data is already allocated to NAICS codes. A NAICS to IO sector crosswalk was used to allocate flows to appropriate IO sectors. When duplicate entries existed across the two datasets, the NEI value was subtracted from the TRI value. If the remainder of such calculation was &lt; 0, the TRI value was removed from the dataset. If the remainder value was &gt; 0, that remainder was recorded in addition to the NEI value, but tagged separately to allow users to filter out if necessary.</li> <li>•All NEI nonpoint source emissions data were manually allocated to IO sectors based on economic flows across sectors. Urban and rural compartment allocations were conducted using ZIP codes provided by NEI and Census population data.</li> </ul> <p><b>For Energy and Transportation Activities</b></p> <ul style="list-style-type: none"> <li>•Emissions for energy and transportation activities were collected from and used as reported by outside sources, as documented on slide 13. Emissions from mobile combustion were adjusted to provide gross estimates that reflect military platforms.</li> </ul>
Emissions to Water	<p><b>For DoD EnvIO</b></p> <ul style="list-style-type: none"> <li>•TRI point source emissions data is already allocated to NAICS codes. A NAICS to IO sector crosswalk was used to allocate flows to appropriate IO sectors.</li> </ul>
Emissions to Soil	<p><b>For DoD EnvIO</b></p> <ul style="list-style-type: none"> <li>•TRI point source emissions data is already allocated to NAICS codes. A NAICS to IO sector crosswalk was used to allocate flows to appropriate IO sectors.</li> </ul>
Pesticides	<p><b>For DoD EnvIO</b></p> <ul style="list-style-type: none"> <li>•NASS surveys agricultural chemical use by crop type on a rotating basis. Surveys from 2001 back to 2013 were collected to capture data for all relevant crops.</li> <li>•Because data were from different years, the dataset was scaled according to pesticide usage in 2007. This was done using crop production data in physical units (kg, bushel, etc.) from NASS for each crop.</li> <li>•Crops were then assigned to NAICS codes and then crosswalked to IO sector codes.</li> <li>•Compartments were mapped to ImpactWorld+ pesticide application compartments based on most similar crops (e.g., tree fruits = apples, grains = wheat, root vegetables = potatoes, etc.)</li> </ul>
Agricultural Nutrient Runoff	<p><b>For DoD EnvIO</b></p> <ul style="list-style-type: none"> <li>•Data were taken from a variety of sources, including academic literature, EPA Science Advisory Board reports, counts of animals in production, associated waste produced, USDA modeling, and waste management systems from the US GHG Inventory. Best estimates were compared and collated from these sources (see slide 13 for sources).</li> <li>•Runoff from crops was primarily quantified using the 2007 NRCS CEAP report. Runoff quantities were manually allocated to IO sectors by crop type and compartment (surface vs. groundwater).</li> <li>•Runoff from animal agriculture was quantified using a combination of sources. Total waste produced by animal type was gathered from the EPA GHG Inventory along with fate of nitrogen fractions and checked with EPA and USDA inventories. Runoff quantities were manually allocated to IO sectors based on type of animal.</li> </ul>

# B Matrix: Notes (Labor)

Environmental Flow Category	Notes
Employment	<p><b>For DoD EnvIO</b></p> <ul style="list-style-type: none"> <li>•The Bureau of Labor Statistics (BLS) tracks annual employment by industry, but at the 3-digit NAICS level. Thus, the IO sectors were more granular in some industry groupings. In such cases, employment data was allocated according to each industry’s percentage of total economic output for the relevant industry grouping.</li> <li>•All data mapped to NAICS codes were then crosswalked to relevant IO sectors.</li> </ul>
Worker Health, Fatal Incidents	<p><b>For DoD EnvIO</b></p> <ul style="list-style-type: none"> <li>•BLS tracks most annual fatalities at the 5-digit NAICS level. Due to confidentiality issues, some fatalities are reported at high levels. In such cases, the higher level data was allocated to 5-digit NAICS codes according to each industry segment’s percentage of the high level grouping’s total economic output.</li> <li>•All data mapped to NAICS codes were then crosswalked to relevant IO sectors.</li> </ul>
Worker Health, Disability Incidents	<p><b>For DoD EnvIO</b></p> <ul style="list-style-type: none"> <li>•BLS tracks most non-fatal injuries and illnesses at the 5-digit NAICS level. Due to confidentiality issues, some fatalities are reported at high levels. In such cases, the higher level data was allocated to 5-digit NAICS codes according to each industry segment’s percentage of the high level grouping’s total economic output.</li> <li>•This data was provided by BLS according to industry and BLS Nature Code.</li> <li>•All industry data was mapped to NAICS codes were then crosswalked to relevant IO sectors.</li> </ul>

# 1. Data Documentation Notes

C. Life Cycle Impact Characterization and Valuation Method – C Matrix

# C Matrix: Overview

- **Summary:** The C Matrix records all impact characterization factors used to translate environmental flows into midpoint and endpoint impacts. To enhance calculation efficiency, the C Matrix also records valuation factors that values endpoint impacts.
- **File Name:** Final\_C\_Matrix.xlsb
- **Matrix Dimensions:**
  - **Rows [i]:** 10,594 environmental flows, organized by environmental compartment and location
  - **Columns [j]:** 73 midpoint, endpoint, and valuation categories
  - **Cells [i,j]:** Total amount of impact [j], recorded in appropriate impact units, resulting from one unit of environmental flow [i], recorded in appropriate elementary flow units
- **Notes:**
  - As standardized in life cycle impact assessment practice, impacts are grouped into three broad categories: (1) midpoints, (2) endpoints, and (3) valuation. Data sources and general notes are covered in slides 20-27.

# C Matrix: Midpoint Impact Categories

Impact Category	CF Unit	LCIA Method	Notes/References
Climate change	kg CO2-eq/ElemFlow Unit	IMPACTWorld+ Beta (July 2014)	<ul style="list-style-type: none"> <li>De Schryver A.M., Brakke K.W., Goedkoop M.J. and Huijbregts M.A., 2009. Characterization factors for global warming in life cycle assessment based on damages to humans and ecosystems. Environmental Science and Technology 43(6) p.1689-1695.</li> </ul>
Human toxicity, respiratory effects, inorganics	kg PM2-5-eq/ElemFlow Unit	IMPACTWorld+ Beta (July 2014)	<ul style="list-style-type: none"> <li>Humbert S., Marshall J.D., Shaked S., Spadaro J., Nishioka Y., Preiss P.H., McKone T.E., Horvath A. and Jolliet O., 2011. Intake fractions for particulate matter: Recommendations for life cycle assessment. Environmental Science and Technology, 45 (11) 4808-4816.</li> </ul>
Human toxicity, respiratory effects, organics	kg NMVOC-eq/ElemFlow Unit	IMPACTWorld+ Beta (July 2014)	<ul style="list-style-type: none"> <li>Goedkoop, M.J., Spriensma, R., 2001. The Eco-Indicator 99 A damage oriented method for Life Cycle Impact Assessment – Methodology Report. Third edition, 19 March 2015. <a href="http://www.rivm.nl/dsresource?type=pdf&amp;disposition=inline&amp;objectid=rivmp:56589&amp;versionid=&amp;subobjectname">http://www.rivm.nl/dsresource?type=pdf&amp;disposition=inline&amp;objectid=rivmp:56589&amp;versionid=&amp;subobjectname</a>.</li> </ul>
Human toxicity, carcinogens, unspecified	CTUh/ElemFlow Unit	IMPACTWorld+ Beta (July 2014)	<ul style="list-style-type: none"> <li>Hauschild M., Huijbregts M., Jolliet O., Margni M., MacLeod M., van de Meent D., Rosenbaum R.K., McKone T., 2008. Building a model based on scientific consensus for Life Cycle Impact: Assessment of Chemicals: the Search for Harmony and Parsimony. Environmental Science and Technology 42(19), 7032-7036.</li> <li>Henderson A., Hauschild M., Van de Meent D., Huijbregts M.A.J., Larsen H.F., Margni M., McKone T.E., Payet J., Rosenbaum R.K., Jolliet O., 2011. USEtox fate and ecotoxicity factors for comparative assessment of toxic releases in Life Cycle Assessment: Sensitivity to key chemical properties. International Journal of Life Cycle Assessment 16(8), 701-709.</li> <li>Humbert S., Manneh R., Shaked S., Horvath A., Deschênes L., Jolliet O. and Margni M., 2009. Assessing regional intake fractions and human damage factors in North America. Science of the Total Environment 407, 4812-4820.</li> <li>Rosenbaum R.K., Bachmann T.K., Gold L.S., Huijbregts M.A.J., Jolliet O., Juraske R., Koehler A., Larsen H.F., MacLeod M., Margni M., McKone T.E., Payet J., Schuhmacher M., Van de Meent D., Hauschild M.Z., 2008. USEtox-The UNEP-SETAC toxicity model: recommended characterisation factors for human toxicity and freshwater ecotoxicity in Life Cycle Impact Assessment. International Journal of Life Cycle Assessment 13(7) 532-546.</li> <li>Rosenbaum R.K., McKone T. and Jolliet O., 2009. CKow - A Dynamic Model for Chemical Transfer to Meat and Milk. Environmental Science and Technology 43(21), 8191-8198.</li> <li>Rosenbaum R.K., Huijbregts M., Henderson A., Margni M., McKone T.E., van de Meent D., Hauschild M.Z., Shaked S., Li D.S, Gold L.S, Jolliet O., 2011. USEtox human exposure and toxicity factors for comparative assessment of toxic releases in Life Cycle Analysis: Sensitivity to key chemical properties. International Journal of Life Cycle Assessment 16(8), 710-727.</li> <li>Rosenbaum R.K., Margni M., Jolliet O., 2007. A flexible matrix algebra framework for the multimedia multipathway modeling of release to impacts. Environment International 33(5), 624-634.</li> </ul>
Human toxicity, carcinogens, unspecified, pesticide residue			
Human toxicity, non-carcinogens, unspecified			
Human toxicity, non-carcinogens, unspecified, pesticide residue			
Aquatic ecosystem toxicity	CTUe/ElemFlow Unit	IMPACTWorld+ Beta (July 2014)	

# C Matrix: Midpoint Impact Categories (continued)

Impact Category	CF Unit	LCIA Method	Notes/References
Land use	m <sup>2</sup> -yr arable-eq/ElemFlow Unit	IMPACTWorld+ Beta (July 2014)	<ul style="list-style-type: none"> <li>Saad R., Koellner T., and Margni M., 2012. Land use impacts on freshwater and erosion regulation and water purification: A spatial approach for a global scale level. Submitted in: International Journal of Life Cycle Assessment.</li> <li>Saad R., Margni M., Koellner T., Wittstock B. and Deschênes L., 2011. Assessment of land use impacts on soil ecological functions: development of spatially differentiated characterization factors within a Canadian context. International Journal of Life Cycle Assessment, 16(3), 198-211.</li> </ul>
Terrestrial acidification	kg SO <sub>2</sub> -eq/ElemFlow Unit	IMPACTWorld+ Beta (July 2014)	<ul style="list-style-type: none"> <li>Roy, P.-O., L. Deschênes and M. Margni (2013). "Uncertainty and spatial variability in characterization factors for aquatic acidification at the global scale." The International Journal of Life Cycle Assessment: 1-9. <a href="http://dx.doi.org/10.1007/s11367-013-0683-0">http://dx.doi.org/10.1007/s11367-013-0683-0</a></li> <li>Roy P.-O., Deschênes L. and Margni M., 2012. Spatially-explicit global scale sensitivity indicator(s) for terrestrial acidification compatible with endpoint modeling in Life Cycle Impact Assessment. Submitted in: Environmental Science and Technology.</li> <li>Roy, P.-O., M. Huijbregts, L. Deschênes and M. Margni (2012). "Spatially-differentiated atmospheric source-receptor relationships for nitrogen oxides, sulfur oxides and ammonia emissions at the global scale for life cycle impact assessment." Atmospheric Environment 62: 74-81.</li> <li>Roy, P. O., L. Deschênes and M. Margni (2012). "Life Cycle Impact Assessment of Terrestrial Acidification: Modeling Spatially Explicit Soil Sensitivity at the Global Scale." Environ. Sci. Technol. 46(15): 8270-8278.</li> </ul>
Freshwater eutrophication	kg PO <sub>4</sub> -eq/ElemFlow Unit	IMPACTWorld+ Beta (July 2014)	<ul style="list-style-type: none"> <li>Helmes R., Huijbregts M.A.J., Henderson A.D., Jolliet O., 2012. Spatially explicit fate factors of freshwater phosphorous emissions at the global scale. International Journal of Life Cycle Assessment, on-line first (<a href="http://dx.doi.org/10.1007/s11367-012-0382-2">http://dx.doi.org/10.1007/s11367-012-0382-2</a>).</li> </ul>
Marine eutrophication	kg N-eq/ElemFlow Unit	IMPACTWorld+ Beta (July 2014)	<ul style="list-style-type: none"> <li>Bulle, C., Fantke, P., Jolliet, O., Humbert, S., Margni, M., Kashef, S. IMPACT World+. March 2015. <a href="http://www.impactworldplus.org/en/index.php">http://www.impactworldplus.org/en/index.php</a>.</li> </ul>
Water deprivation	m <sup>3</sup> deprived/ElemFlow Unit	IMPACTWorld+ Beta (July 2014)	<ul style="list-style-type: none"> <li>Boulay A.-M., Bouchard C., Bulle C., Deschênes L., and Margni M., 2011. Categorizing water for LCA inventory. International Journal of Life Cycle Assessment, 16(7), 639-651. Springer Berlin / Heidelberg.</li> <li>Boulay A.-M., Bulle C., Bayart J.-B., Deschênes L., and Margni M., 2011. Regional Characterization of Freshwater Use in LCA: Modeling Direct Impacts on Human Health. Environmental Science &amp; Technology, 45(20), 8948-8957. American Chemical Society.</li> <li>Maendly R. and Humbert S., 2012. Empirical characterization model and factors assessing aquatic biodiversity damages of hydropower water use. Submitted in: International Journal of Life Cycle Assessment.</li> </ul>
Water use	m <sup>3</sup> /ElemFlow Unit	DoD EnvIO (March 2015)	<ul style="list-style-type: none"> <li>This impact category was developed for tracking water withdrawals and returns for the purpose of deriving a water footprint. This impact category is duplicative with the "Water deprivation" impact category and is not further modeled to endpoint nor valuation.</li> </ul>

# C Matrix: Midpoint Impact Categories (continued)

Impact Category	CF Unit	LCIA Method	Notes/References
Fossil energy use	kg oil-eq/ElemFlow Unit	ReCiPe (2008, v1.11)	<ul style="list-style-type: none"> <li>Goedkoop M.J., Heijungs R, Huijbregts M., De Schryver A.;Struijs J., Van Zelm R, ReCiPe 2008, A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level; First edition Report I: Characterisation; 6 January 2009, <a href="http://www.lcia-recipe.net">http://www.lcia-recipe.net</a>.</li> </ul>
Mineral use	kg iron-eq/ElemFlow Unit	ReCiPe (2008, v1.11)	
Human noise exposure, outdoor	person-Pa-s / person-Pa-s	Curcurachi & Heijungs (2014)	<ul style="list-style-type: none"> <li>Cucurachi, S., Heijungs, R., Ohlau, K., 2012. Towards a general framework for including noise impacts in LCA. International Journal of Life Cycle Assessment 17, 471-487.</li> <li>Cucurachi, S., Heijungs, R., 2014. Characterization factors for life cycle assessment. Science of the Total Environment 468-469, 280-291.</li> <li>The characterization factors in the Cucurachi and Heijungs articles were adjusted to account for U.S. population densities.</li> </ul>
Human noise exposure, indoor			
Occupational health, fatal injuries	incidents/ElemFlow Unit	DoD EnvIO (March 2015)	<ul style="list-style-type: none"> <li>Based on Scanlon K, Gray G., Francis R., Lloyd S., LaPuma P., The work environment disability-adjusted life year for use with life cycle assessment: a methodological approach. Environmental Health 2013, 12:21.</li> <li>Custom developed for the DoD, this impact methodology translates full-time equivalent (FTE) labor input into incidents of fatal injuries, incidents of long-term disabilities, and person-days of short-term disabilities.</li> </ul>
Occupational health, life-long disabilities			
Occupational health, short-term disabilities	Person-days/ElemFlow Unit		

# C Matrix: Endpoint Impact Categories

Impact Category	CF Unit	LCIA Method	Notes/References
Climate change	kg CO2-eq/kg CO2-eq	IMPACTWorld+ Beta (July 2014)	<ul style="list-style-type: none"> <li>Bulle, C., Fantke, P., Jolliet, O., Humbert, S., Margni, M., Kashef, S. IMPACT World+. March 2015. <a href="http://www.impactworldplus.org/en/index.php">http://www.impactworldplus.org/en/index.php</a>.</li> <li>Pachauri, R. K., Reisinger, A. (Eds.) Intergovernmental Panel on Climate Change, Climate Change 2007: Synthesis Report. Geneva, Switzerland. pp 104. March 2015. <a href="http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_synthesis_report.htm">http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_synthesis_report.htm</a>.</li> </ul>
Human health, respiratory inorganics	DALY/kg PM2-5-eq	IMPACTWorld+ Beta (July 2014)	<ul style="list-style-type: none"> <li>Bulle, C., Fantke, P., Jolliet, O., Humbert, S., Margni, M., Kashef, S. IMPACT World+. March 2015. <a href="http://www.impactworldplus.org/en/index.php">http://www.impactworldplus.org/en/index.php</a>.</li> </ul>
Human health, respiratory organics	DALY/kg NMVOC-eq		
Human health, cancer, unspecified	DALY/CTUh		
Human health, cancer, unspecified, pesticide residue			
Human health, non-cancer, unspecified			
Human health, non-cancer, unspecified, pesticide residue			
Human health, water depletion			
Human health, noise, human exposure, outdoor	DALY/person-Pa-s	Curcurachi & Heijungs (2014)	<ul style="list-style-type: none"> <li>Cucurachi, S., Heijungs, R., 2014. Characterization factors for life cycle assessment. Science of the Total Environment 468-469, 280-291.</li> </ul>
Human health, noise, human exposure, indoor			
Human health, occupational health, fatal injuries	DALY/incident	DoD EnvIO (March 2015)	<ul style="list-style-type: none"> <li>Based on Scanlon K, Gray G., Francis R., Lloyd S., LaPuma P., The work environment disability-adjusted life year for use with life cycle assessment: a methodological approach. Environmental Health 2013, 12:21.</li> <li>Custom developed for the DoD, this impact methodology translates incidents of fatal injuries, incidents of long-term disabilities, and person-days of short-term disabilities into weighted disability adjusted life years (DALY).</li> <li>All injury and illness data was manually crosswalked from BLS Nature Codes to the World Health Organization's (WHO) ICD-9 diagnosis codes to derive DALY equivalent. BLS Nature Codes, which describe the nature of the injury or illness, do not consistently align to ICD-9 codes, which characterize the treatment used to address the injury or illness. As such, expert judgment was required to pair BLS Nature Codes to ICD-9 codes. This mapping is consistent with the approach used in Scanlon et al. (2013).</li> </ul>
Human health, occupational health, life-long disabilities			
Human health, occupational health, short-term disabilities	DALY/Person-day		

# C Matrix: Endpoint Impact Categories (continued)

Impact Category	CF Unit	LCIA Method	Notes/References
Ecosystem quality, terrestrial acidification	PDF-m2-yr/kg SO2-eq	IMPACTWorld+ Beta (July 2014)	<ul style="list-style-type: none"> <li>Bulle, C., Fantke, P., Jolliet, O., Humbert, S., Margni, M., Kashef, S. IMPACT World+. March 2015. <a href="http://www.impactworldplus.org/en/index.php">http://www.impactworldplus.org/en/index.php</a>.</li> </ul>
Ecosystem quality, freshwater eutrophication	PDF-m2-yr/kg PO4-eq		
Ecosystem quality, marine eutrophication	PDF-m2-yr/kg N-eq		
Ecosystem quality, water depletion	PDF-m2-yr/m3 deprived		
Ecosystem quality, water table lowering	PDF-m2-yr/m3 deprived		
Ecosystem quality, land use	PDF-m2-yr/ha.yr arable eq		
Ecosystem quality, aquatic ecosystem toxicity	PDF-m2-yr/CTUe		
Ecosystem quality, marine acidification	PDF-m2-yr/kg CO2-eq		
Resource availability, fossil energy use	USD2014/kg oil-eq		
Resource availability, mineral use	USD2014/kg iron-eq		
Resource availability, water depletion	MJ extra/m3 deprived	Pfister et al. (July 2009)	<ul style="list-style-type: none"> <li>Pfister S., Koehler A., Hellweg S., Assessing the Environmental Impacts of Freshwater Consumption in LCA, Environ. Sci. Technol., 2009, 43 (11), pp 4098–4104.</li> </ul>

# C Matrix: Impact Valuation Categories

Impact Category	Valuation Unit	Valuation Method	Notes/References
Climate change	USD2014/kg CO2-eq	U.S. Social Cost of Carbon	<ul style="list-style-type: none"> <li>U.S. interagency Working Group on Social Cost of Carbon. "Technical Support Document: - Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis – Under Executive Order 12866 ". 2013. <a href="https://www.whitehouse.gov/sites/default/files/omb/assets/inforeg/technical-update-social-cost-of-carbon-for-regulator-impact-analysis.pdf">https://www.whitehouse.gov/sites/default/files/omb/assets/inforeg/technical-update-social-cost-of-carbon-for-regulator-impact-analysis.pdf</a></li> <li>Quantifies the economic damages associated with marginal increases in carbon dioxide emissions (IMPACT World+, IPCC, U.S. Interagency Working Group on Social Cost of Carbon) using the Social Cost of Carbon (SCC) valuation factors developed by the United States Interagency Working Group.</li> </ul>
Human health, respiratory inorganics	USD2014/DALY	Weidema (2009)	<ul style="list-style-type: none"> <li>Weidema, B.P., 2009. Using the budget constraint to monetarise impact assessment results. Ecological Economics 68, 1591-1598.</li> <li>The costs associated with the degradation of human health are defined in terms of an individual's willingness-to-pay to ensure a certain level of well-being and the change in economic productivity associated with increased disabled life.</li> <li>Human well-being is measured in terms of an individual's willingness to pay to avoid an injury or illness. This top-down valuation is based on human health risks expressed in terms of disability adjusted life years (DALY). Costs are estimated using a model that assumes that an individual's willingness to pay to avoid the loss of a year of quality life is constrained by their total annual income. For the purposes of this estimate, income is expressed in terms of productive potential under ideal working conditions. This value, which is 129,745 USD2014/DALY, should be adjusted annually for inflation. This potential annual economic production is based on the per-capita Gross Economic Product and adjusted to account for unemployment and underemployment, current health and work-disabling effects, trade barriers, and under education. This method ensures that the value of healthy life is equivalent across all socioeconomic groups.</li> </ul>
Human health, respiratory organics			
Human health, cancer, unspecified			
Human health, cancer, unspecified, pesticide residue			
Human health, non-cancer, unspecified			
Human health, non-cancer, unspecified, pesticide residue			
Human health, water use			
Human health, occupational health, fatal injuries			
Human health, occupational health, life-long disabilities			
Human health, occupational health, short-term disabilities			
Human productivity, respiratory inorganics	USD2014/DALY	Weidema (2009)	<ul style="list-style-type: none"> <li>Weidema, B.P., 2009. Using the budget constraint to monetarise impact assessment results. Ecological Economics 68, 1591-1598.</li> <li>The costs associated with the degradation of human health are defined in terms of an individual's willingness-to-pay to ensure a certain level of well-being and the change in economic productivity associated with increased disabled life.</li> <li>Human productivity is measured as the loss to society associated with the inability of an impacted individual to contribute productively in the economy. This top-down valuation is also based on human health risks expressed in terms of disability adjusted life years (DALY). Costs are estimated as the per-capita decrease in Gross Domestic Product resulting from disabled life. When normalized to the DALY, this cost is 40,326 USD2014/DALY.</li> </ul>
Human productivity, respiratory organics			
Human productivity, cancer, unspecified			
Human productivity, cancer, unspecified, pesticide residue			
Human productivity, non-cancer, unspecified			
Human productivity, non-cancer, unspecified, pesticide residue			
Human productivity, water use			
Human productivity, occupational health, fatal injuries			
Human productivity, occupational health, life-long disabilities			
Human productivity, occupational health, short-term disabilities			

# C Matrix: Impact Valuation Categories (continued)

Impact Category	Valuation Unit	Valuation Method	Notes/References
Ecosystem quality, terrestrial acidification	USD2014/PDF-m2-yr	Weidema (2009)	<ul style="list-style-type: none"> <li>Weidema, B.P., 2009. Using the budget constraint to monetarise impact assessment results. <i>Ecological Economics</i> 68, 1591-1598.</li> <li>The costs associated with the degradation of ecosystem quality are defined in terms of the change in the overall value to society of lost species and ecosystem productivity. This top-down approach estimates these costs to total 0.245 USD2014/PDF.m2.yr. This method is based on calculations triangulating this value from the following three perspectives:               <ul style="list-style-type: none"> <li><b>Choice modeling:</b> A form of stated preference, choice modeling is a technique that infers an individual's willingness to pay for improved ecosystem quality from answers to a survey conducted within a controlled context.</li> <li><b>Relative importance to human health:</b> In this perspective, the value society places on ecosystem quality is approximated relative to the value of human health calculated above. This calculation uses estimates of global species-area and human population together with an assumption that human society aims to protect 10% of the global ecosystems.</li> <li><b>Revealed preference:</b> Using a derivation based on political negotiations related to acidification and nutrient-related impacts, the European Commission's ExternE study provides a lower bound range that only considers a portion of the possible impacts to ecosystem quality.</li> </ul> </li> <li>This triangulation results in a cost range of 0.043 to 0.43 USD2014/PDF.m2.yr, of which the midpoint value is equal to 2% of the income associated with the human health cost estimate calculated above. While there is uncertainty associated with this large range, the base estimate of 0.245 USD2014/PDF.m2.yr is supported by the fact that current environmental protection expenditures in developed countries are 1-2% of Gross Domestic product.</li> </ul>
Ecosystem quality, aquatic eutrophication			
Ecosystem quality, marine eutrophication			
Ecosystem quality, water use			
Ecosystem quality, water table lowering			
Ecosystem quality, land use			
Ecosystem quality, aquatic ecosystem toxicity			
Ecosystem quality, marine acidification			
Ecosystem quality, land use	USD2014/PDF-m2-yr	DoD EnvIO (March 2015)	<ul style="list-style-type: none"> <li>The costs of lost ecosystem productivity directly associated with land use are quantified as the value of conserving highly-productive land. Using revealed preference, this bottom-up valuation approach estimates the value of lost ecosystem productivity as to the cost of preserving one square meter of arable land equivalents for one year under the U.S. Department of Agriculture's Conservation Reserve Program. Estimated at 0.0273 USD2014/m2.yr, this value uses avertive behavior as a proxy value for society's collective willingness to pay to prevent ecosystem damage associated with land use.</li> </ul>

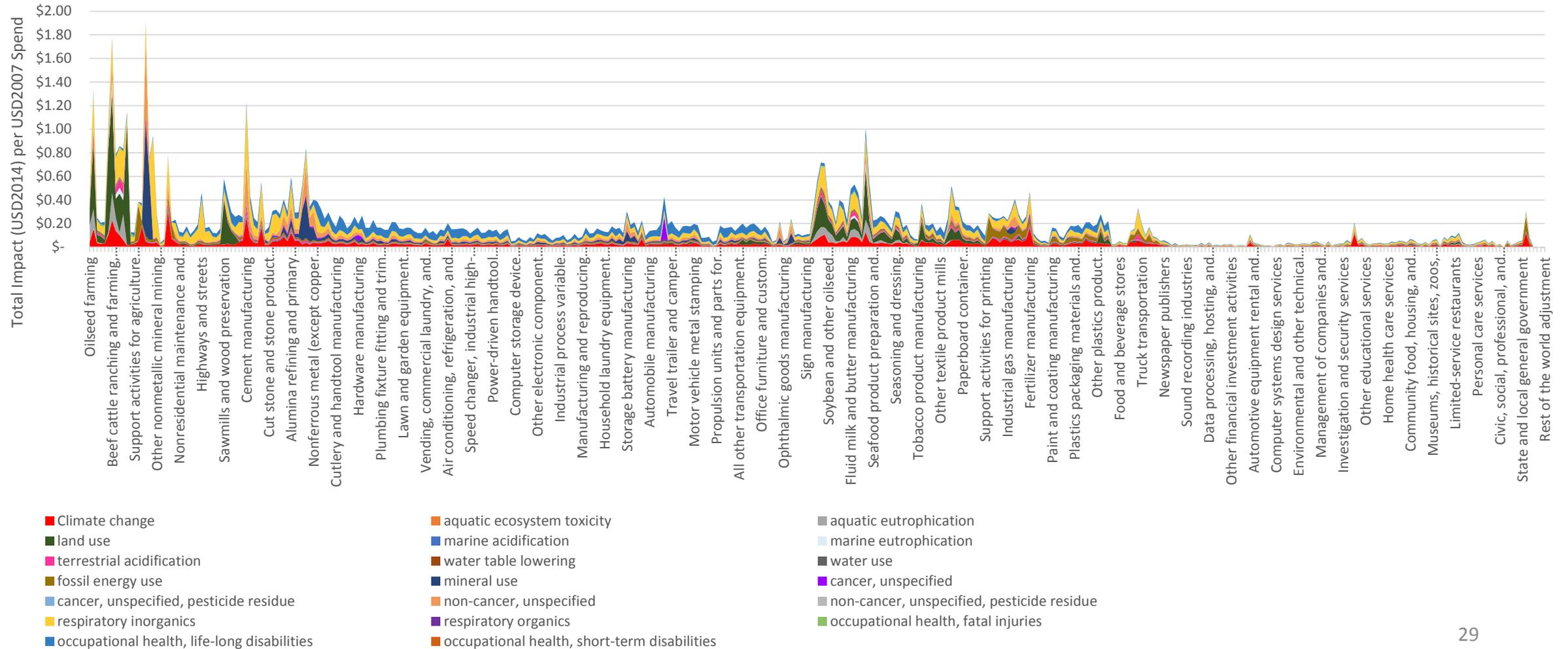
# C Matrix: Impact Valuation Categories (continued)

Impact Category	Valuation Unit	Valuation Method	Notes/References
Resource productivity, water use	USD2014/MJ extra	Weidema (2009)	<ul style="list-style-type: none"> <li>Weidema, B.P., 2009. Using the budget constraint to monetarise impact assessment results. <i>Ecological Economics</i> 68, 1591-1598.</li> <li>This top-down valuation method translates endpoint impacts associated with use of minerals and fossil fuels into economic damages associated with the depletion of non-renewable fossil energy. Estimated at 0.00702 USD 2014/MJ extra, this external cost factor captures the economic value associated with the additional energy required to extract and deliver marginal units of the specified resource to future end users.</li> </ul>
Resource productivity, fossil energy use Resource productivity, mineral use	USD2014/MJ extra	ReCiPe (2008, v1.11)	<ul style="list-style-type: none"> <li>Goedkoop M.J., Heijungs R, Huijbregts M., De Schryver A.;Struijs J., Van Zelm R, ReCiPe 2008, A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level; First edition Report I: Characterisation; 6 January 2009, <a href="http://www.lcia-recipe.net">http://www.lcia-recipe.net</a>.</li> <li>This top-down valuation method translates endpoint impacts associated with use of minerals and fossil fuels into economic damages associated with the depletion of non-renewable fossil energy. Estimated at 0.00702 USD 2014/MJ extra, this external cost factor captures the economic value associated with the additional energy required to extract and deliver marginal units of the specified resource to future end users.</li> </ul>

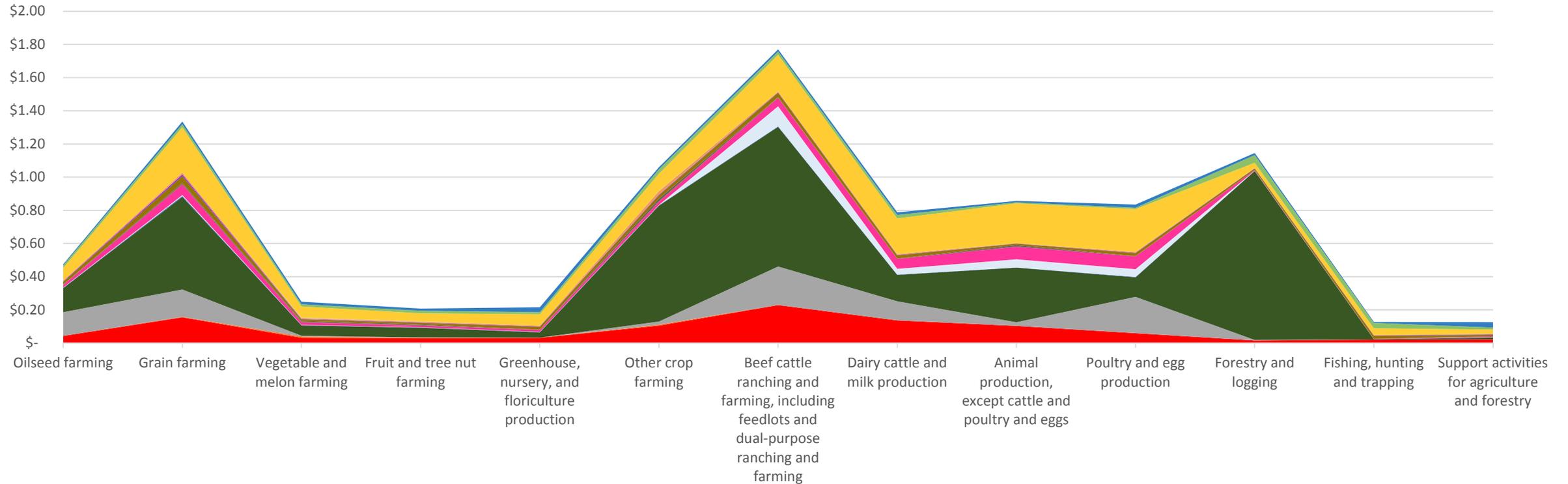
## 2. EnvIO Results

### A. Unnormalized EnvIO Impact-Per-Spend Valuation Results

# Summary of U.S. Economy Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]

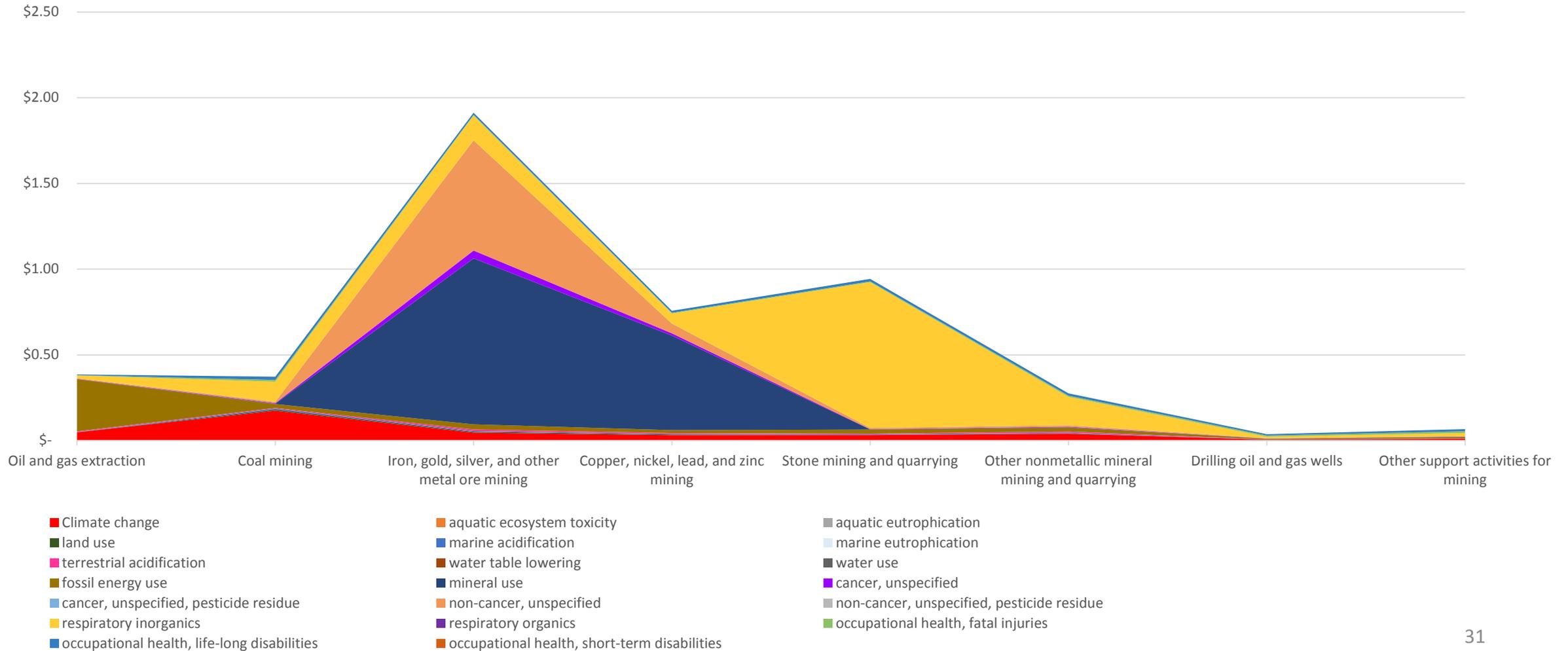


# Agricultural, Forestry, Fish & Hunting Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]

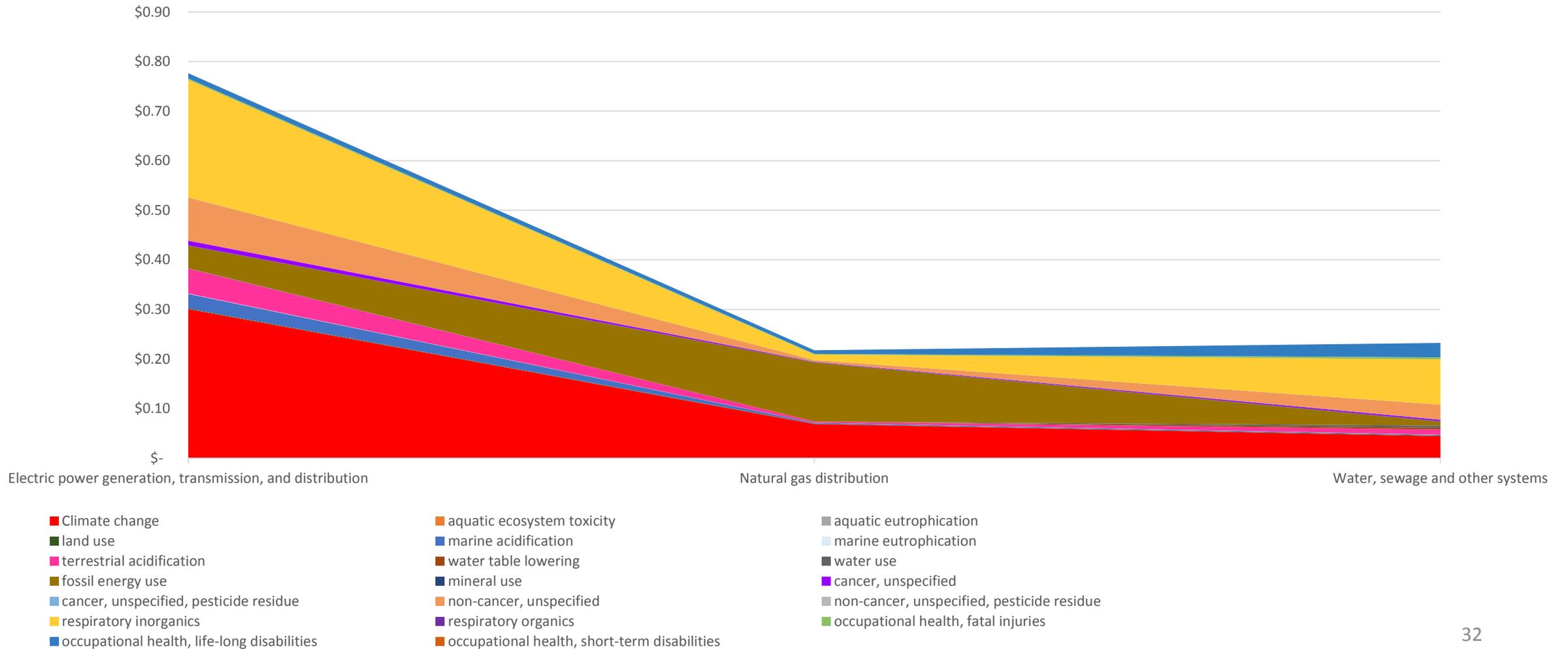


- Climate change
- land use
- terrestrial acidification
- fossil energy use
- cancer, unspecified, pesticide residue
- respiratory inorganics
- occupational health, life-long disabilities
- aquatic ecosystem toxicity
- marine acidification
- water table lowering
- mineral use
- non-cancer, unspecified
- respiratory organics
- occupational health, short-term disabilities
- aquatic eutrophication
- marine eutrophication
- water use
- cancer, unspecified
- non-cancer, unspecified, pesticide residue
- occupational health, fatal injuries

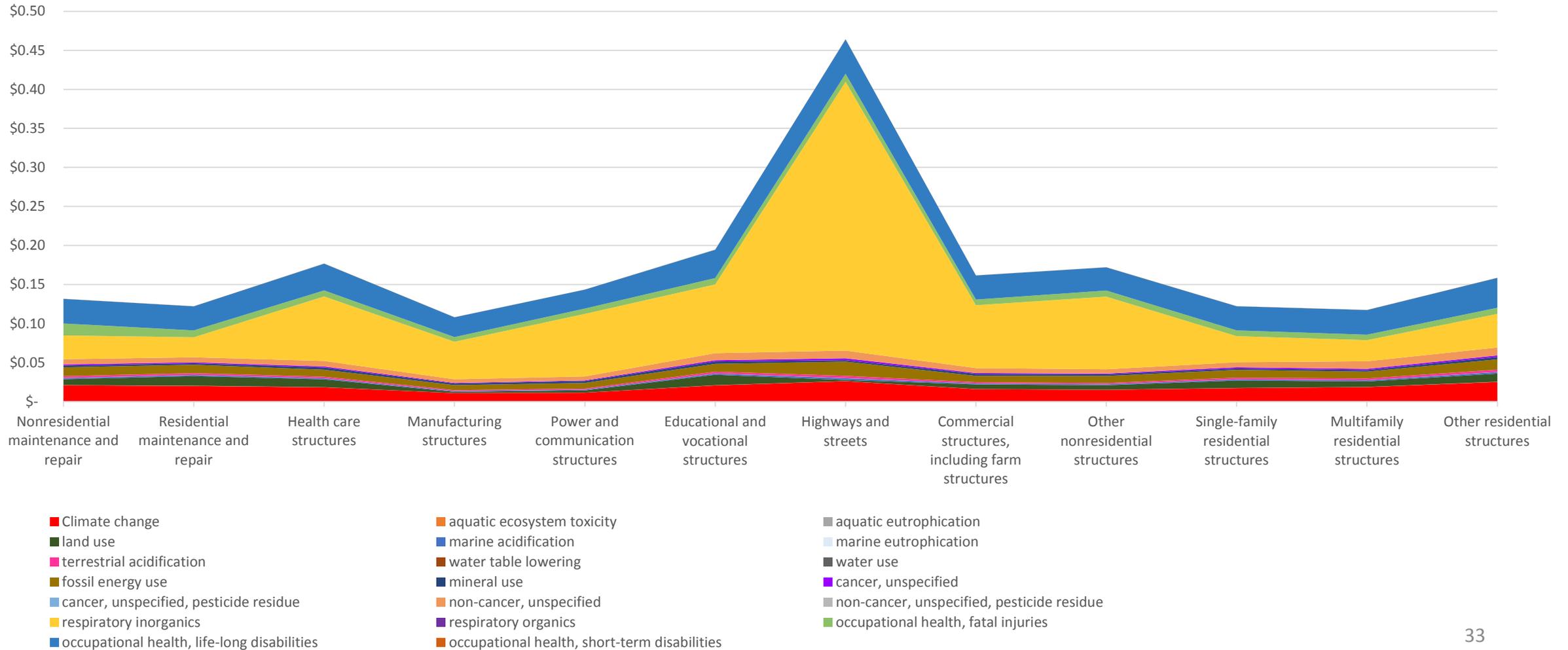
# Mining Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



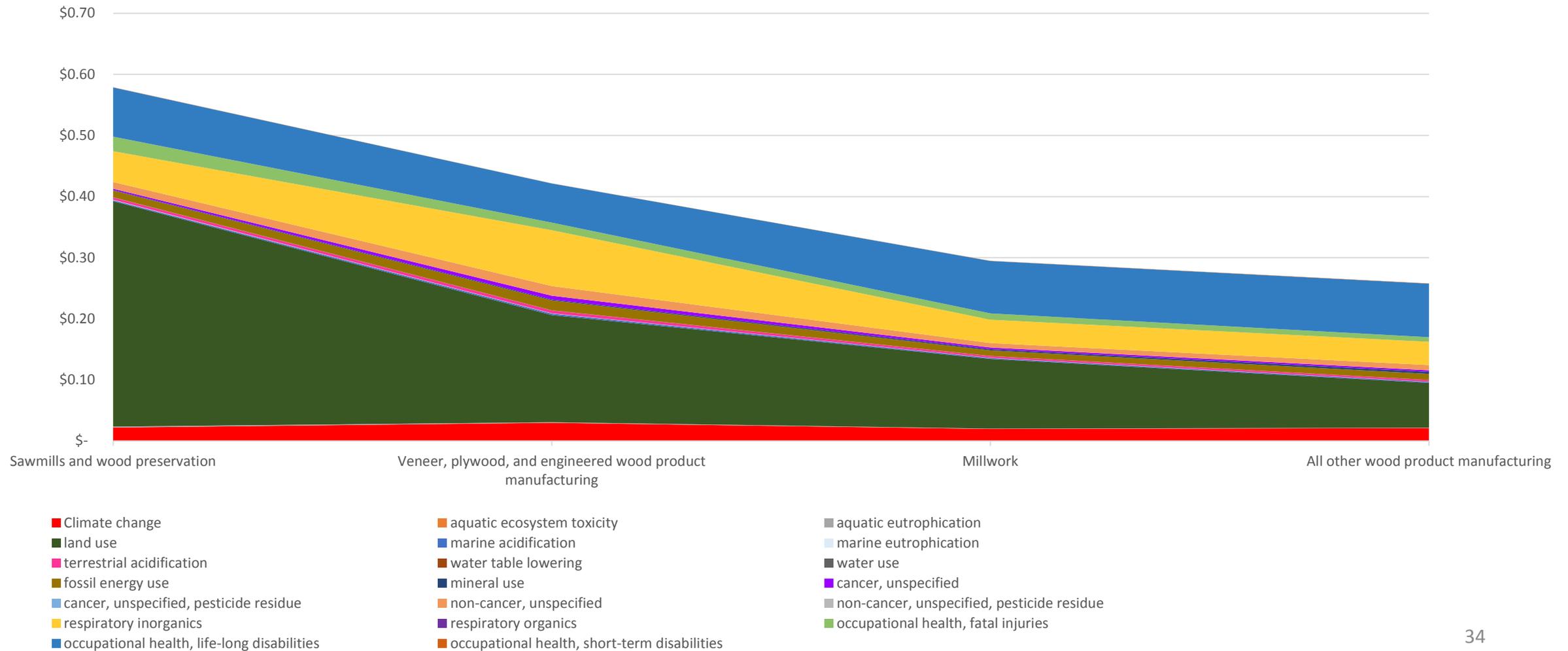
# Utilities Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



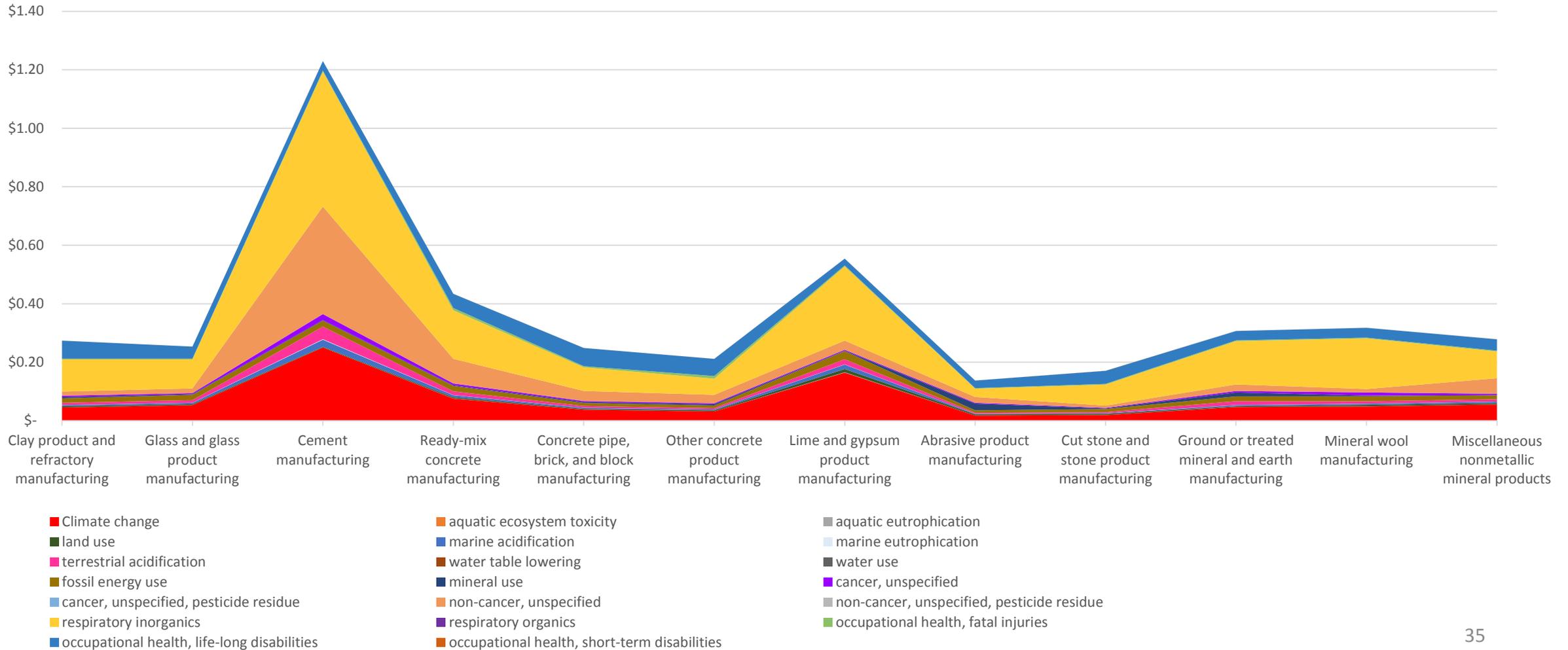
# Construction Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



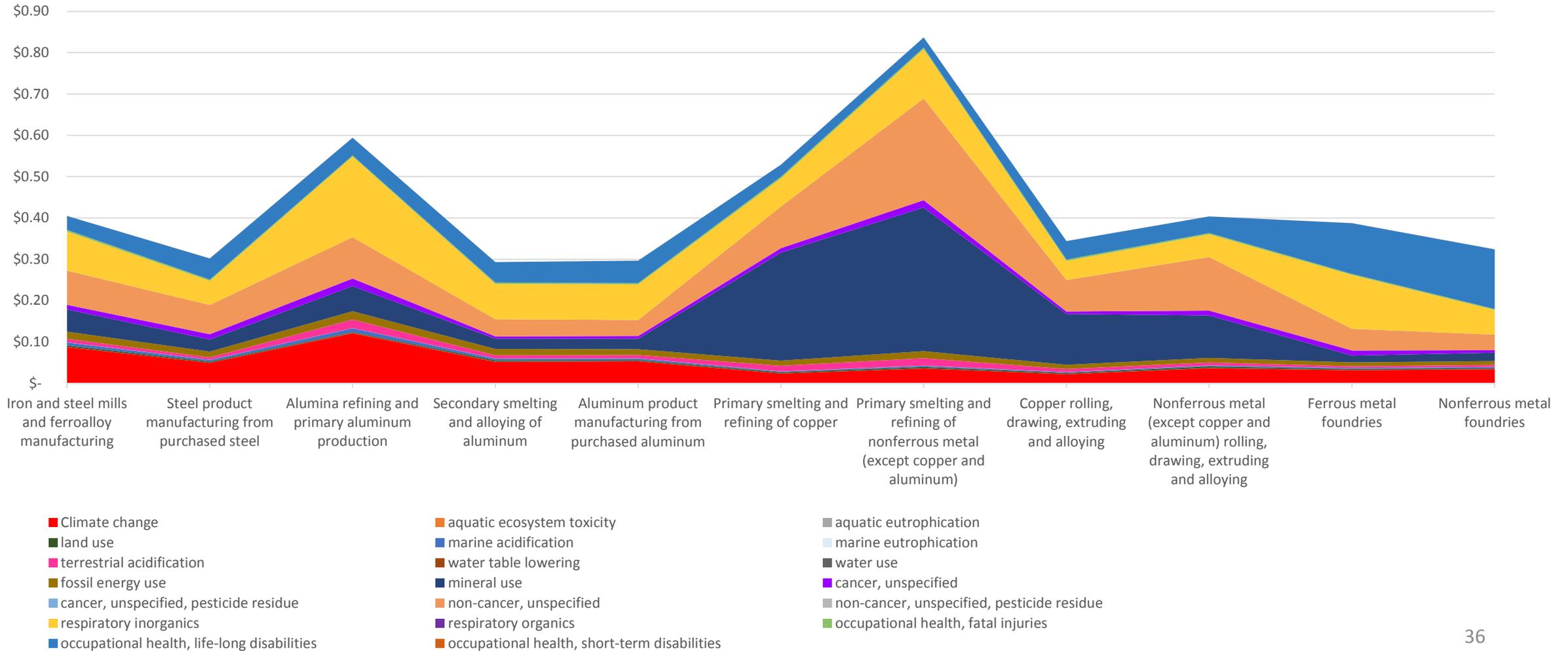
# Wood Products Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



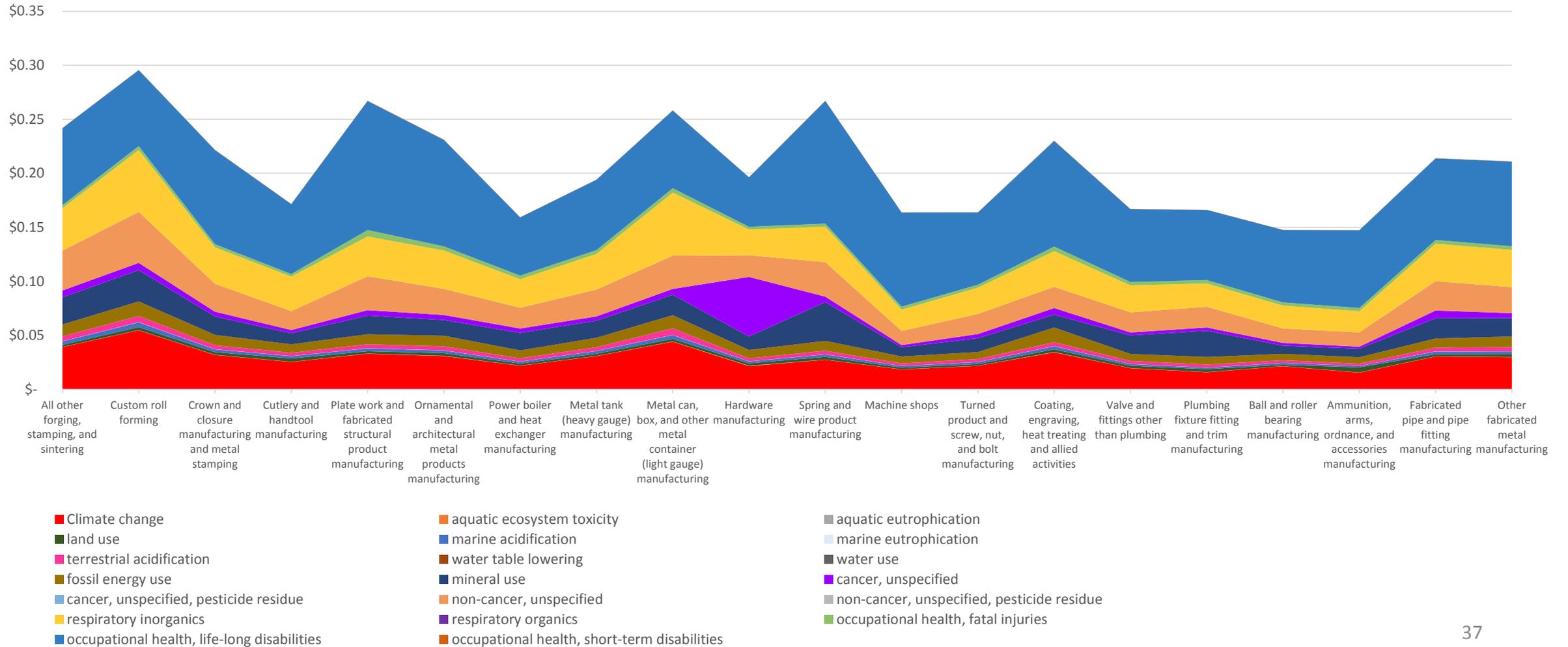
# Nonmetallic Mineral Products Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



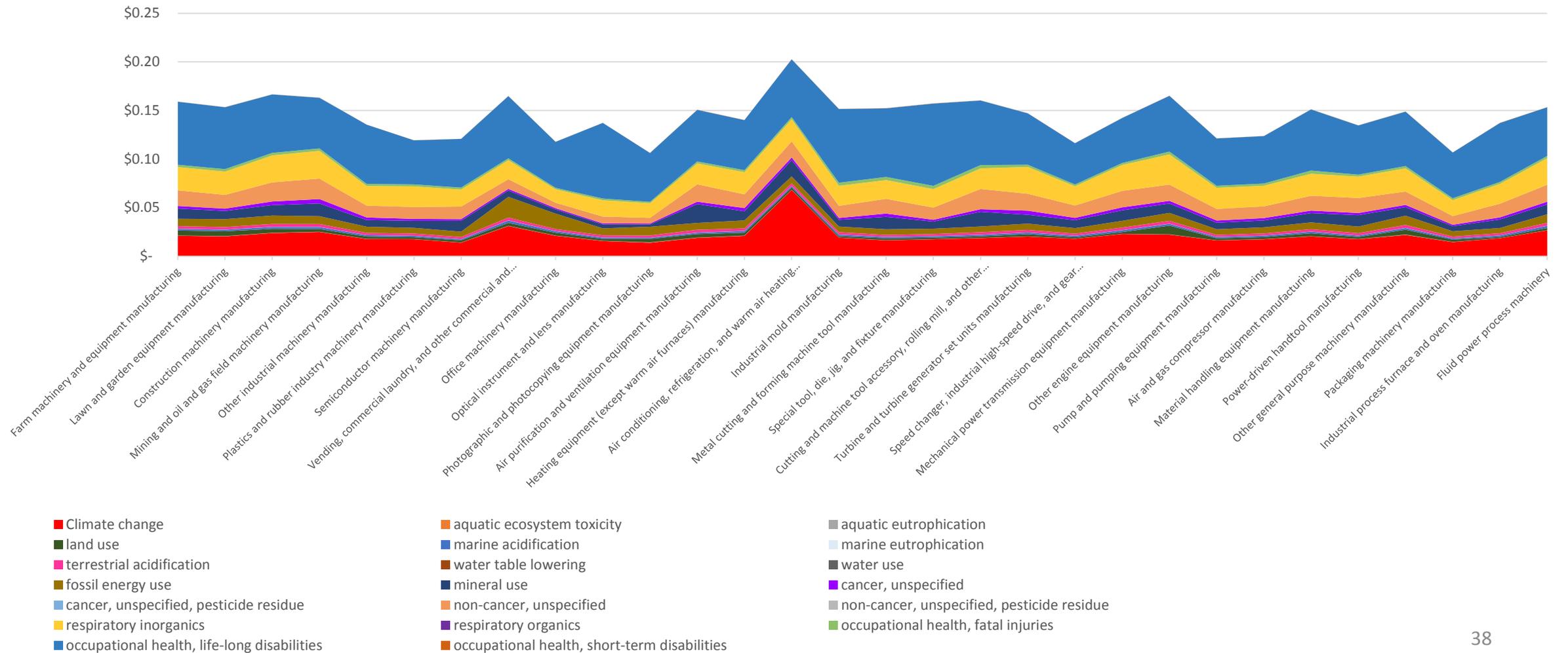
# Primary Metals Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



# Fabricated Metal Products Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]

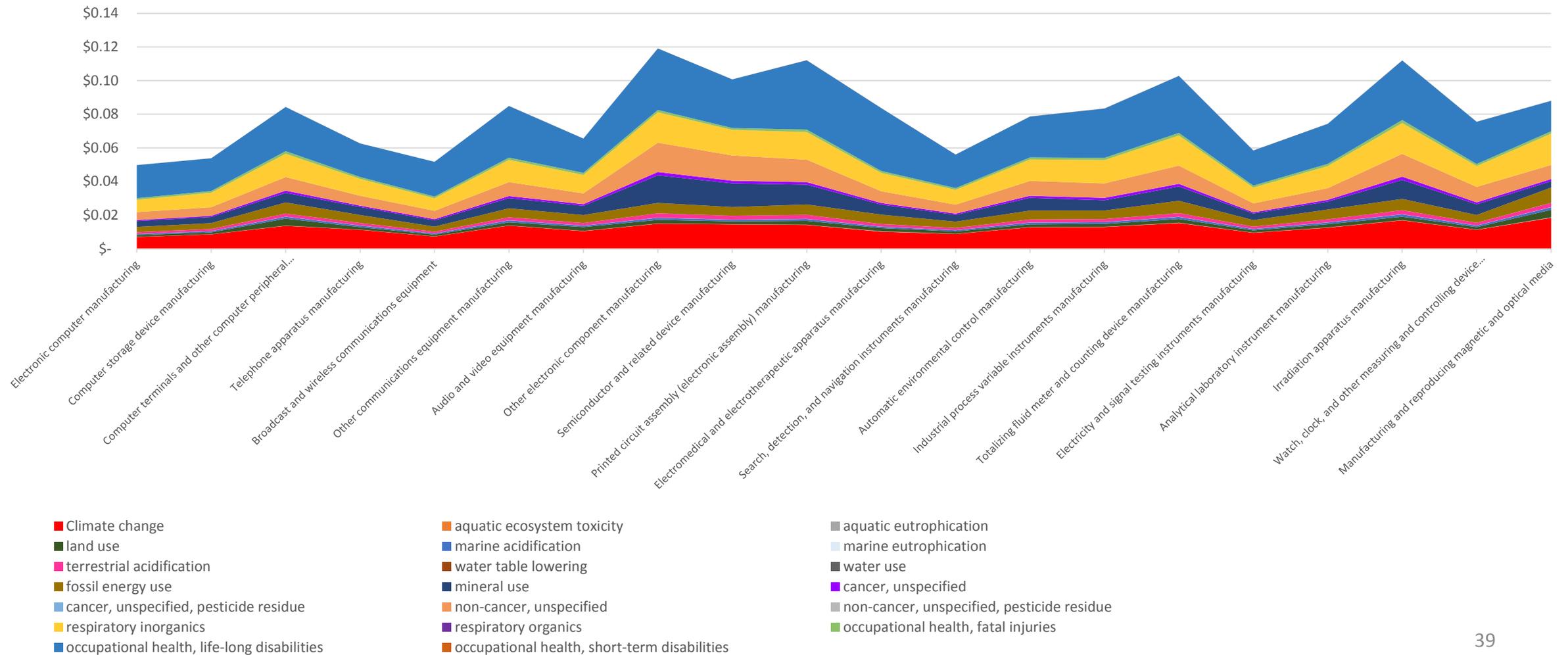


# Machinery Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]

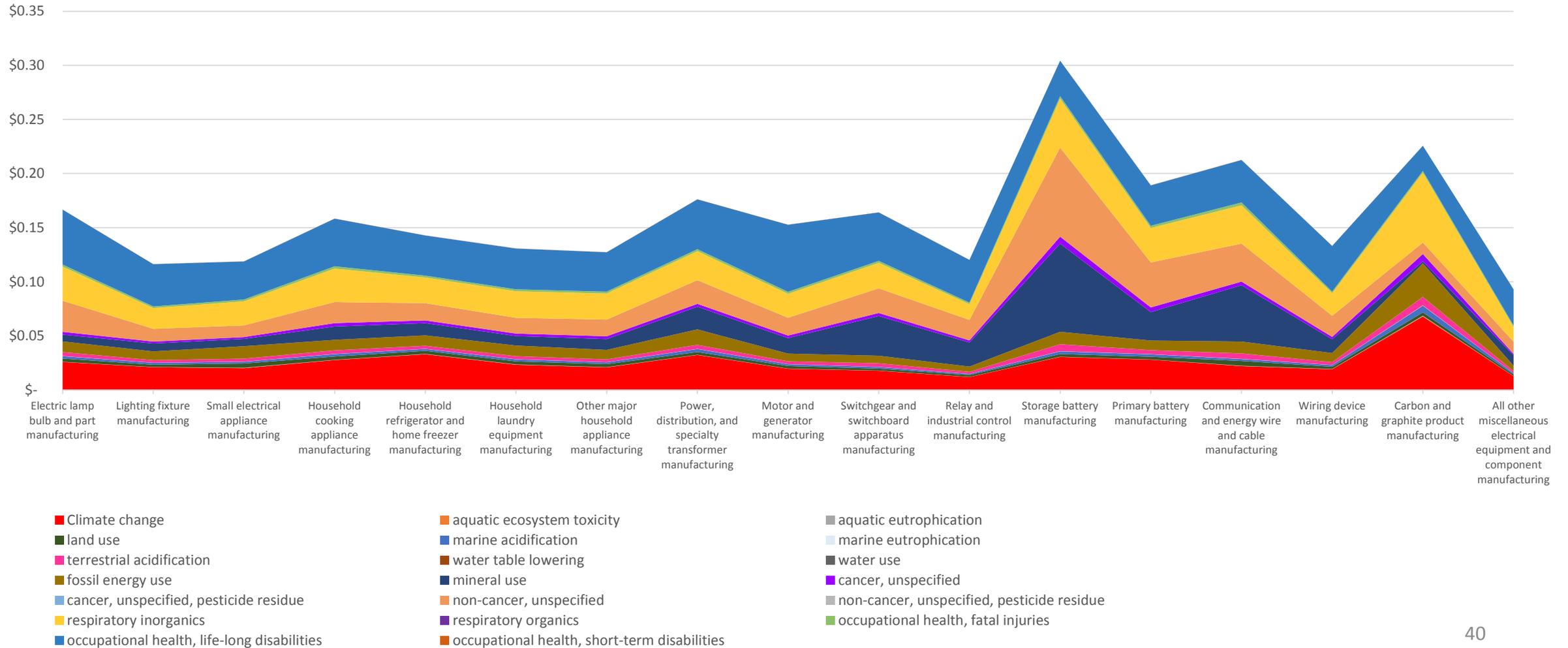


# Computer and Electronic Products Impact Valuation Results

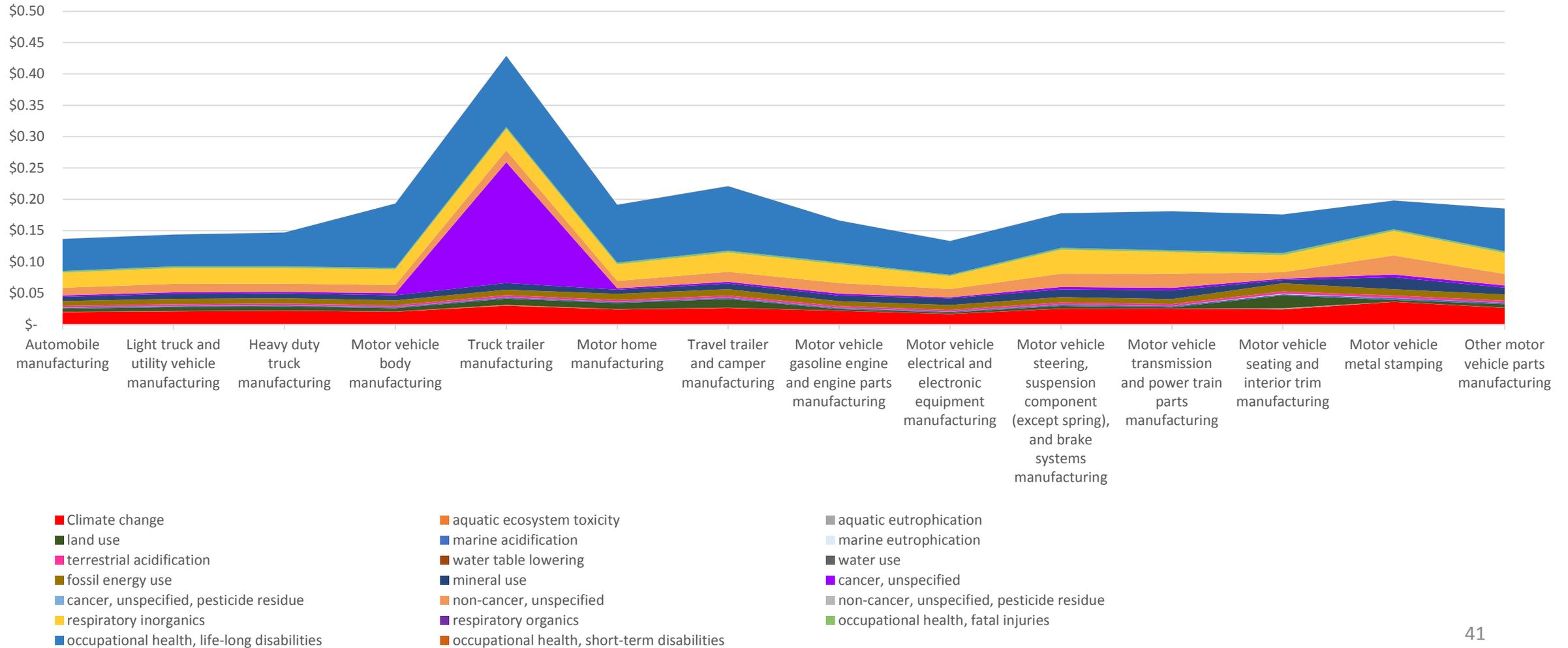
[Total Impacts (USD 2014) per USD2007 of spend]



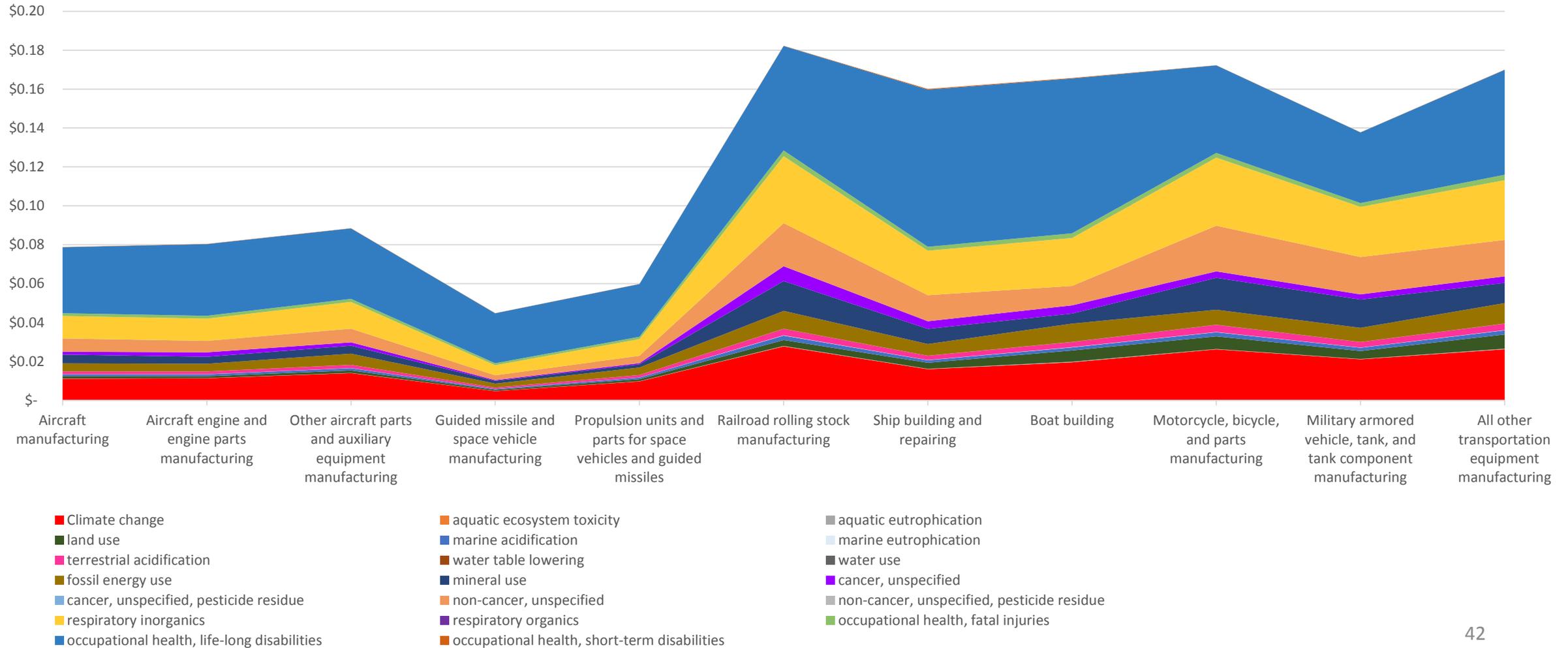
# Electrical Equipment, Appliances, and Components Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



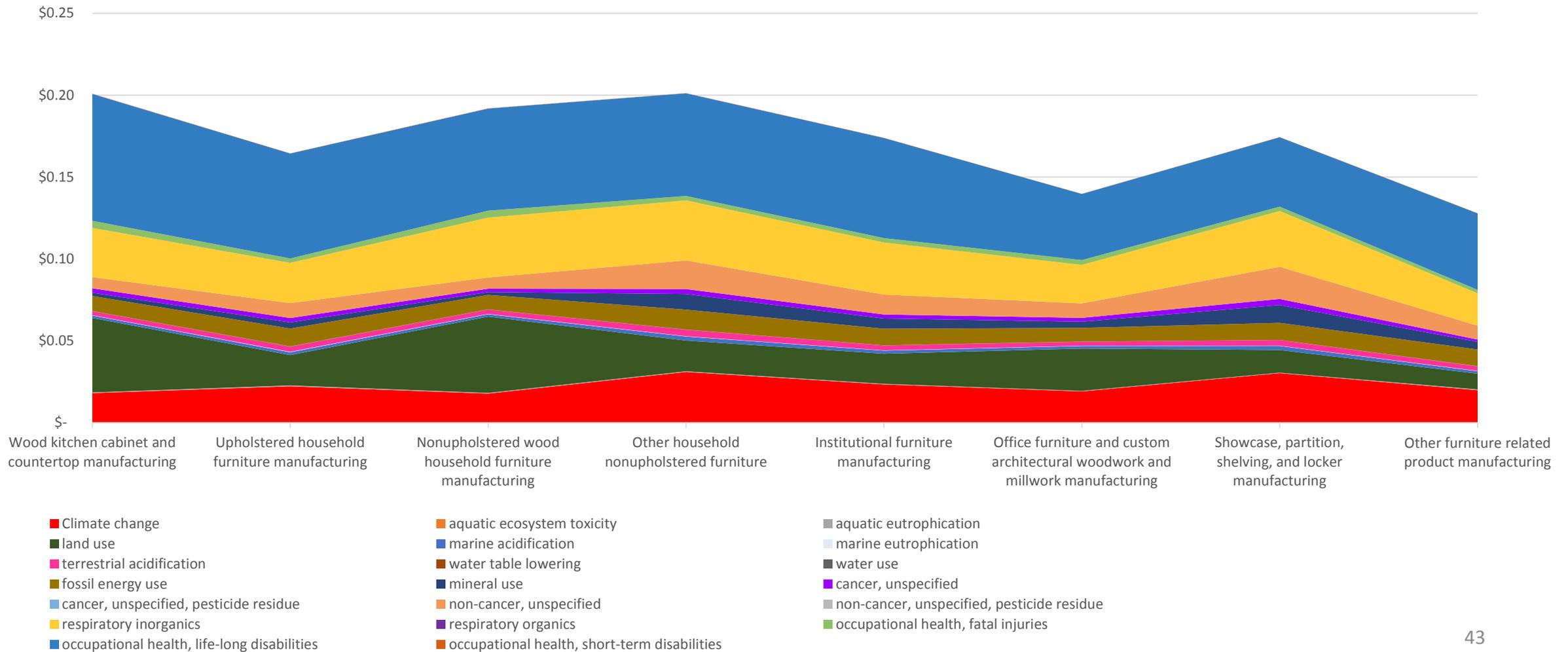
# Motor Vehicles Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



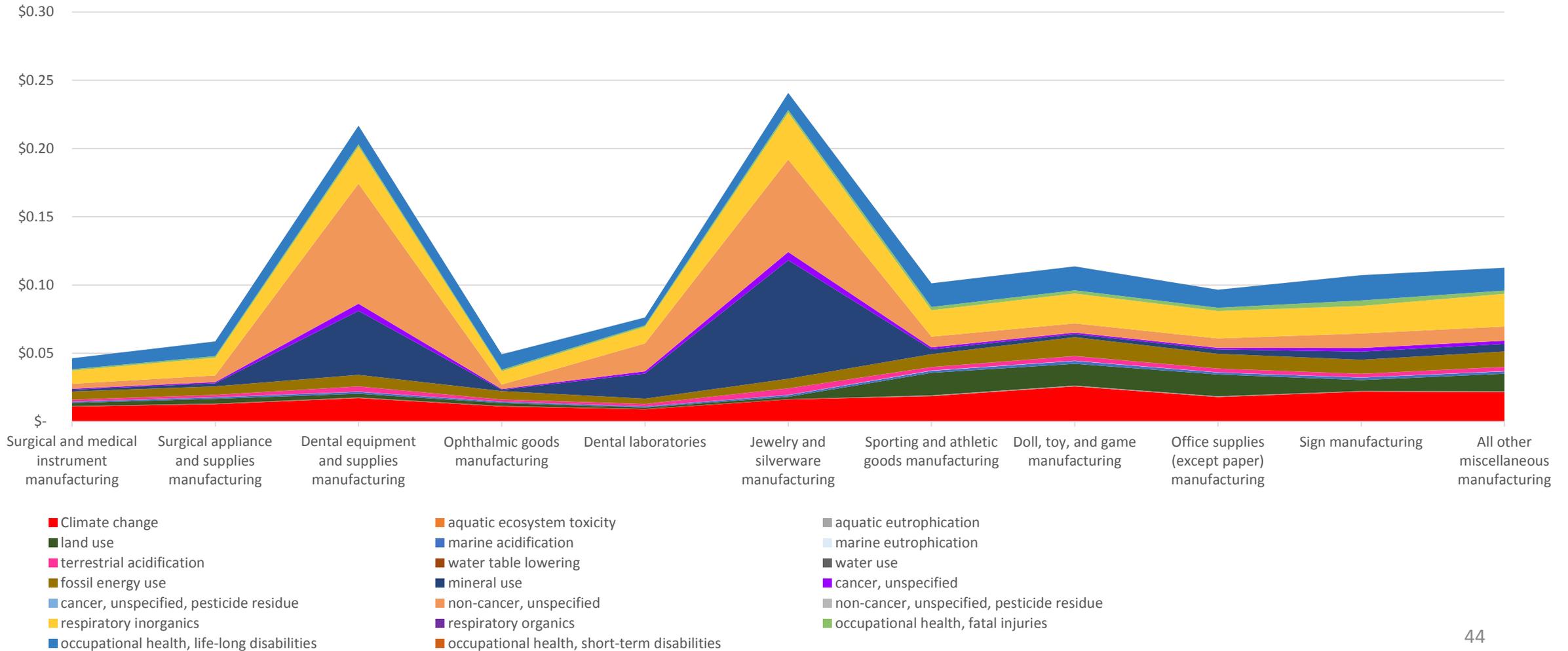
# Other Transportation Equipment Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



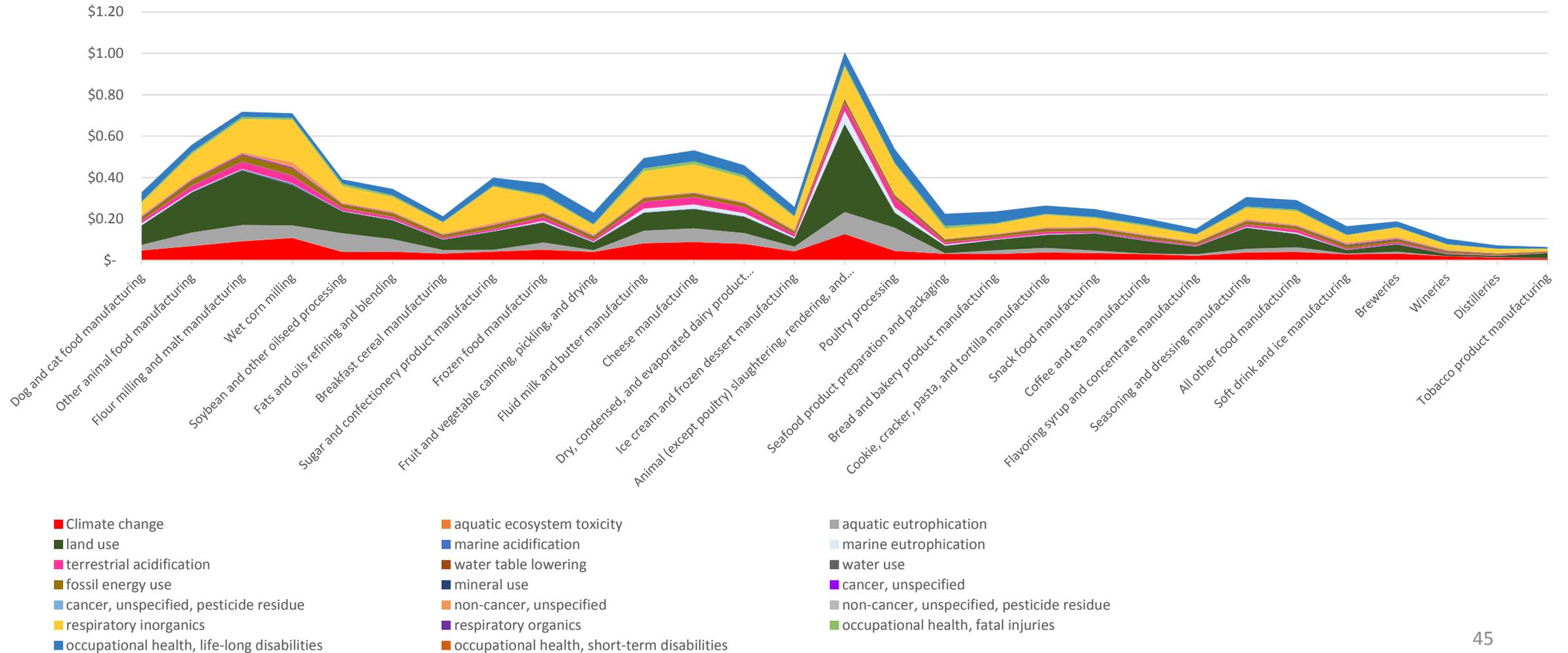
# Furniture and Related Products Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



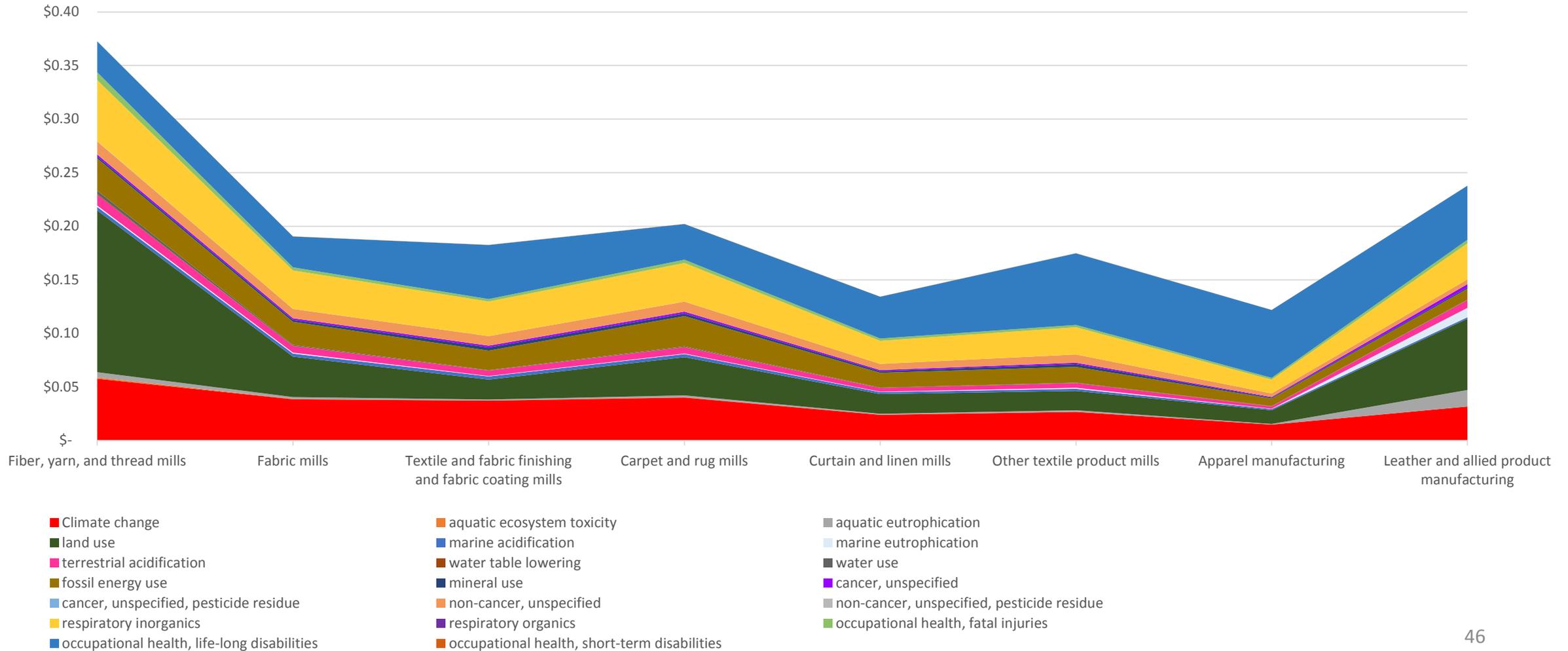
# Misc. Manufacturing Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



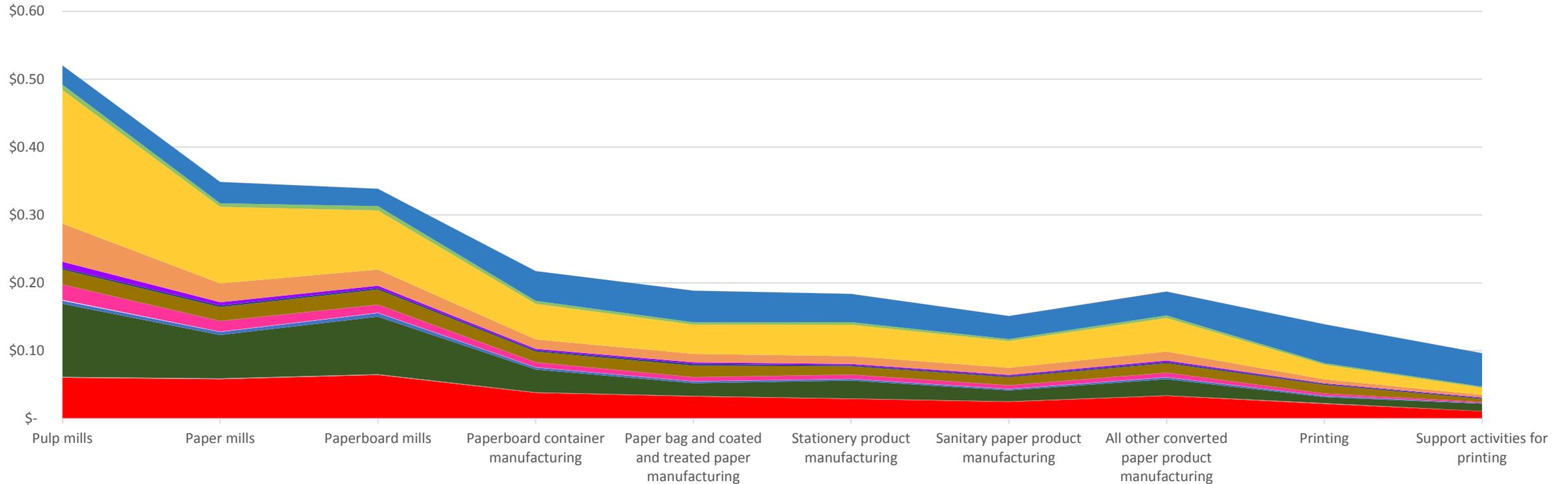
# Food & Beverage and Tobacco Products Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



# Textiles, Apparel, Leather, and Allied Products Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]

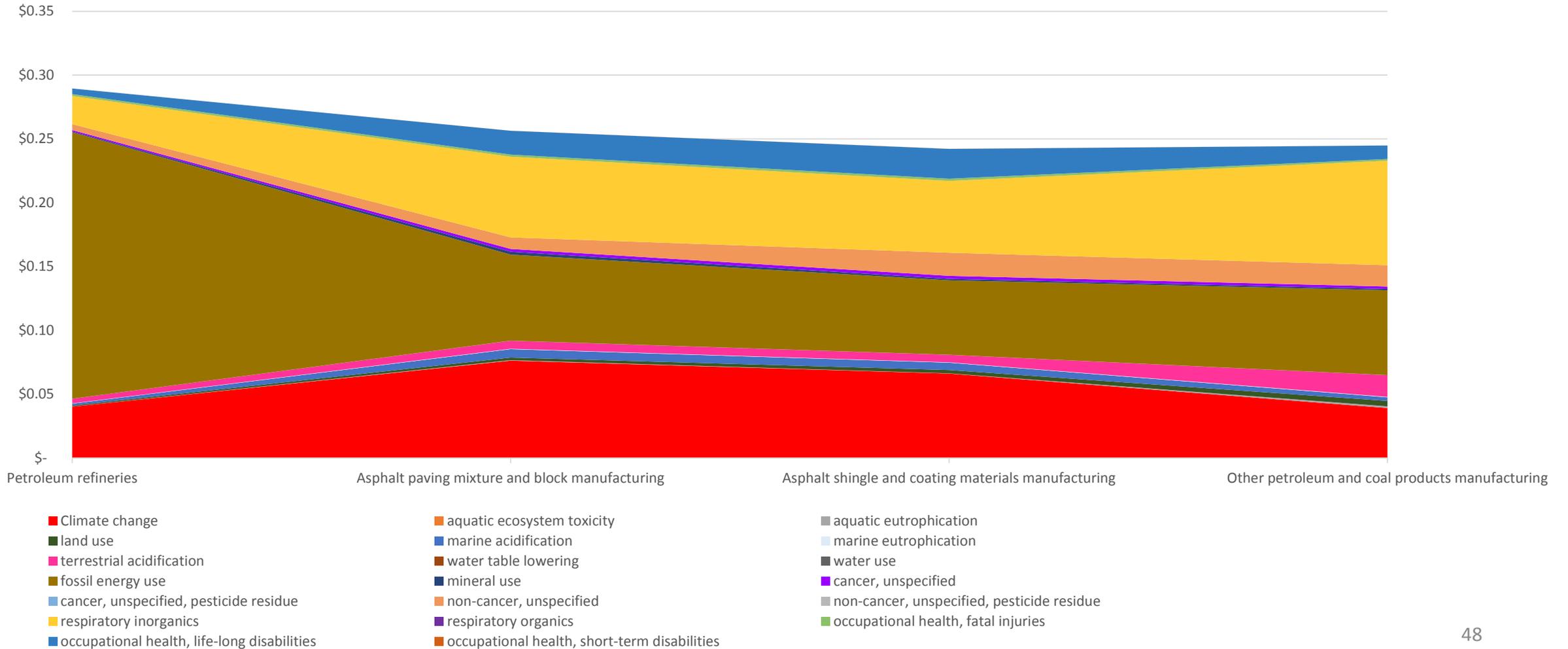


# Paper Products and Printing Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]

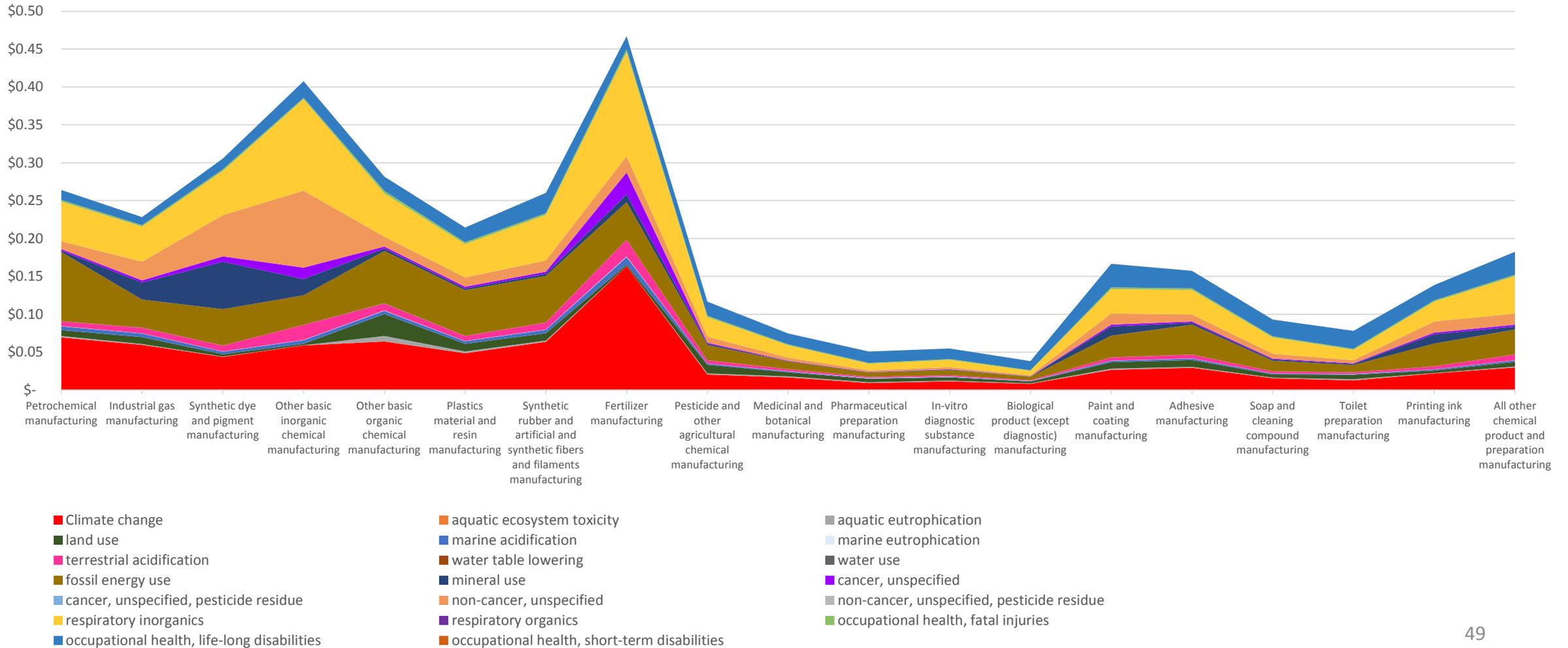


- Climate change
- land use
- terrestrial acidification
- fossil energy use
- cancer, unspecified, pesticide residue
- respiratory inorganics
- occupational health, life-long disabilities
- aquatic ecosystem toxicity
- marine acidification
- water table lowering
- mineral use
- non-cancer, unspecified
- respiratory organics
- occupational health, short-term disabilities
- aquatic eutrophication
- marine eutrophication
- water use
- cancer, unspecified
- non-cancer, unspecified, pesticide residue
- occupational health, fatal injuries

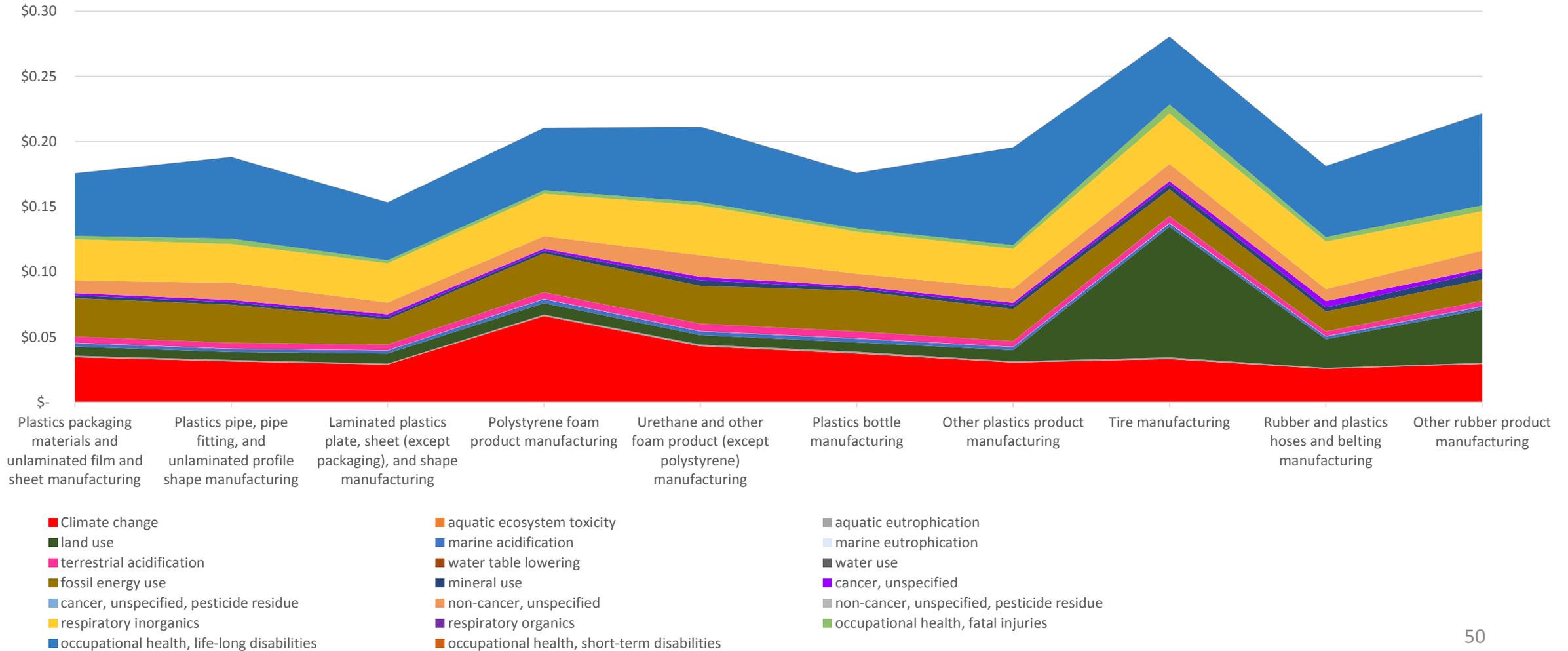
# Petroleum and Coal Products Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



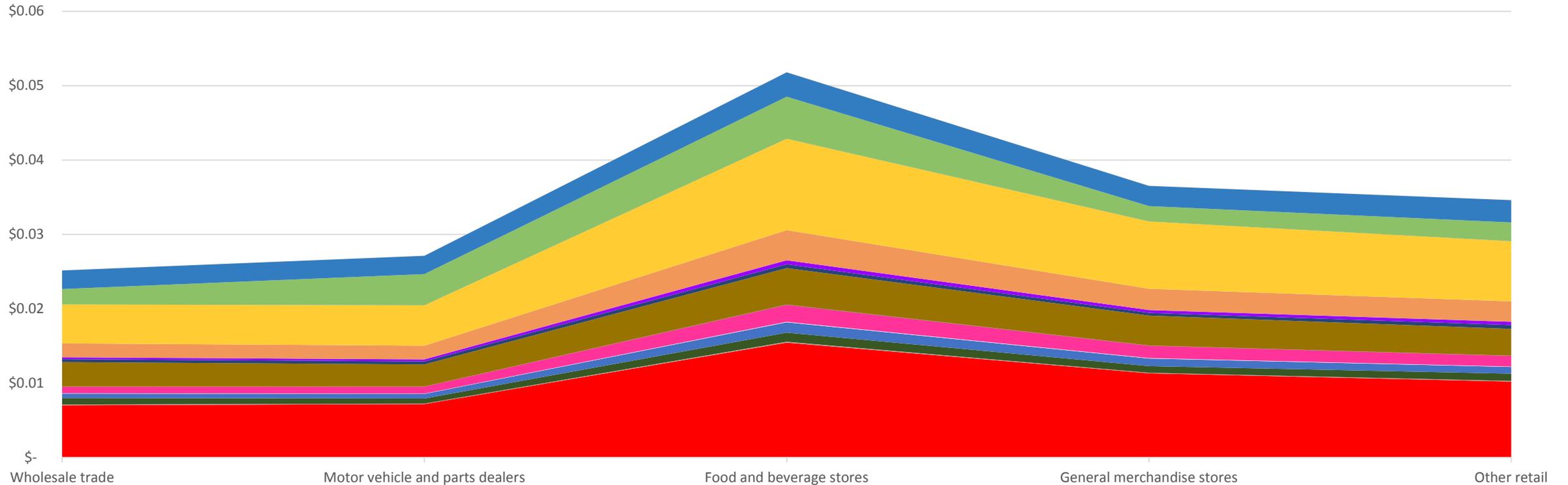
# Chemical Products Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



# Plastics and Rubber Products Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]

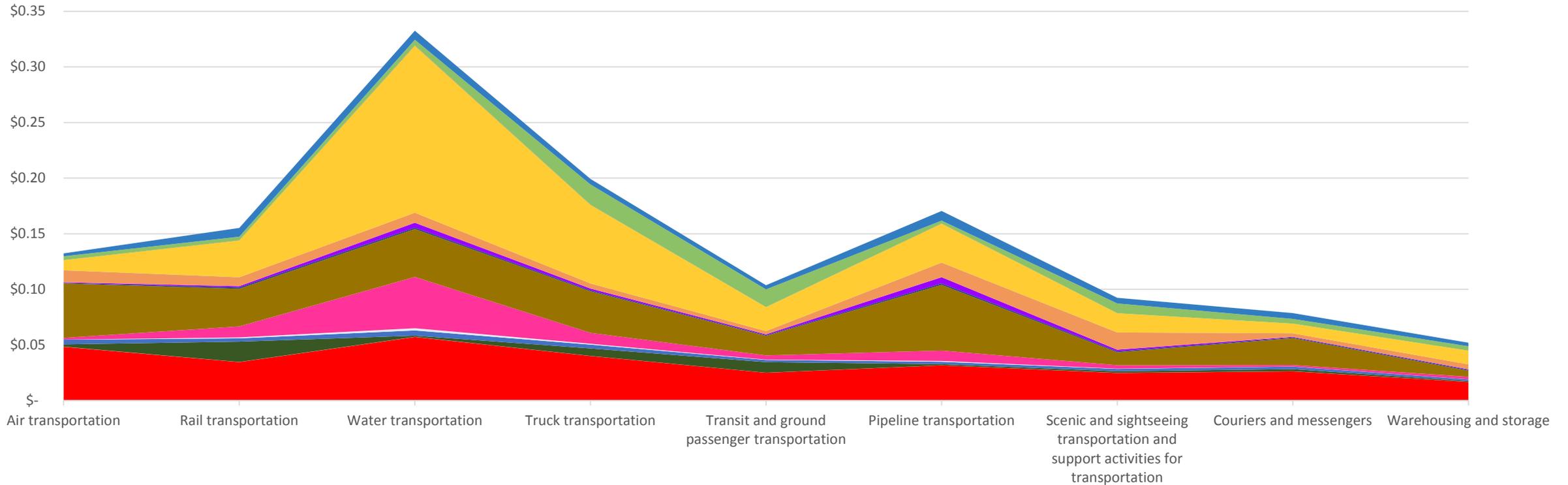


# Wholesale and Retail Trade Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



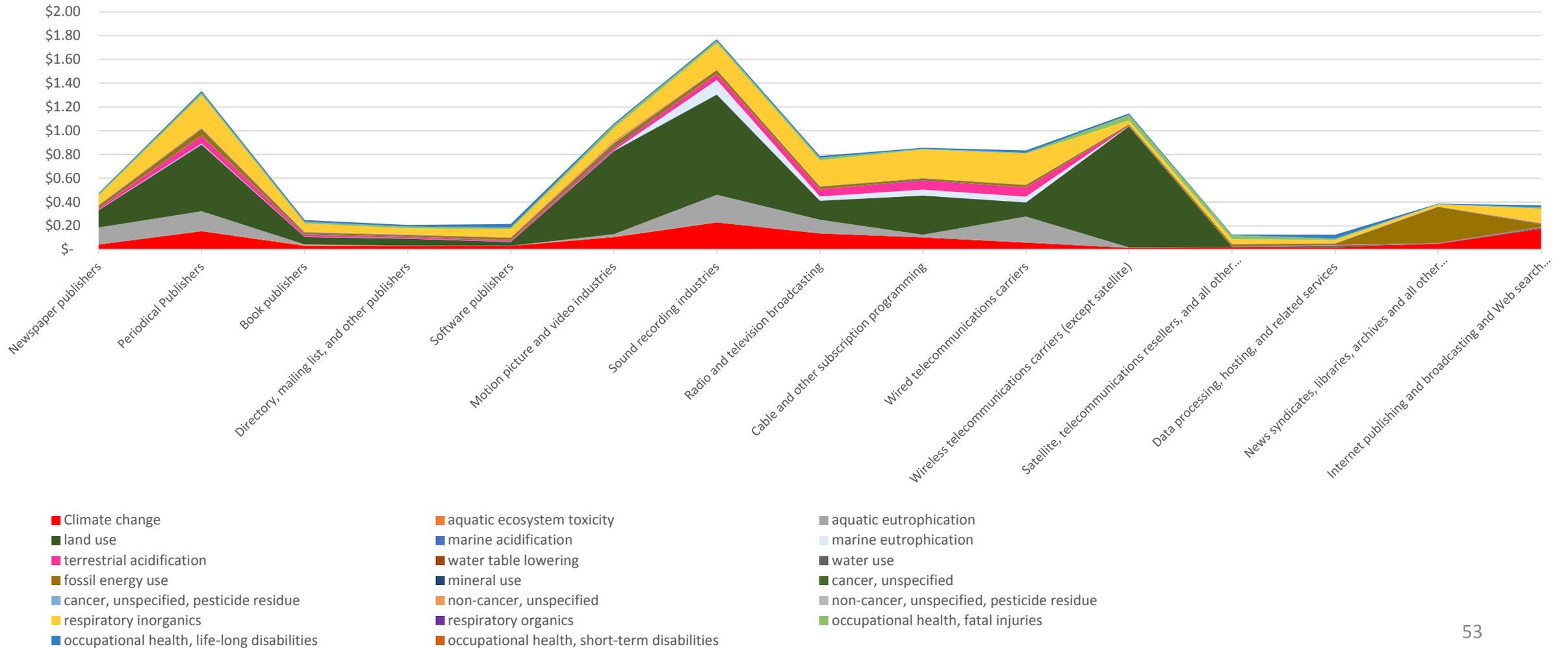
- Climate change
- land use
- terrestrial acidification
- fossil energy use
- cancer, unspecified, pesticide residue
- respiratory inorganics
- occupational health, life-long disabilities
- aquatic ecosystem toxicity
- marine acidification
- water table lowering
- mineral use
- non-cancer, unspecified
- respiratory organics
- occupational health, short-term disabilities
- aquatic eutrophication
- marine eutrophication
- water use
- cancer, unspecified
- non-cancer, unspecified, pesticide residue
- occupational health, fatal injuries

# Transportation and Warehousing Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]

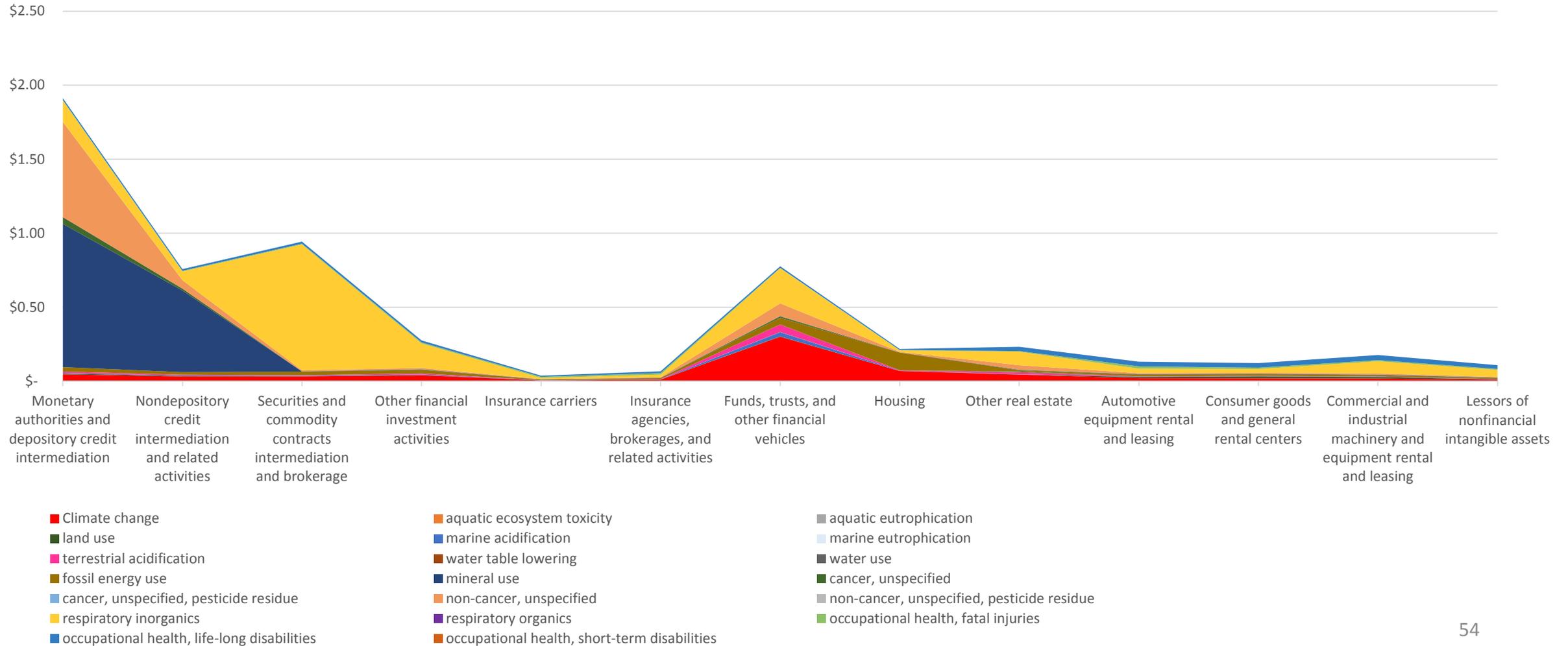


- Climate change
- land use
- terrestrial acidification
- fossil energy use
- cancer, unspecified, pesticide residue
- respiratory inorganics
- occupational health, life-long disabilities
- aquatic ecosystem toxicity
- marine acidification
- water table lowering
- mineral use
- non-cancer, unspecified
- respiratory organics
- occupational health, short-term disabilities
- aquatic eutrophication
- marine eutrophication
- water use
- cancer, unspecified
- non-cancer, unspecified, pesticide residue
- occupational health, fatal injuries

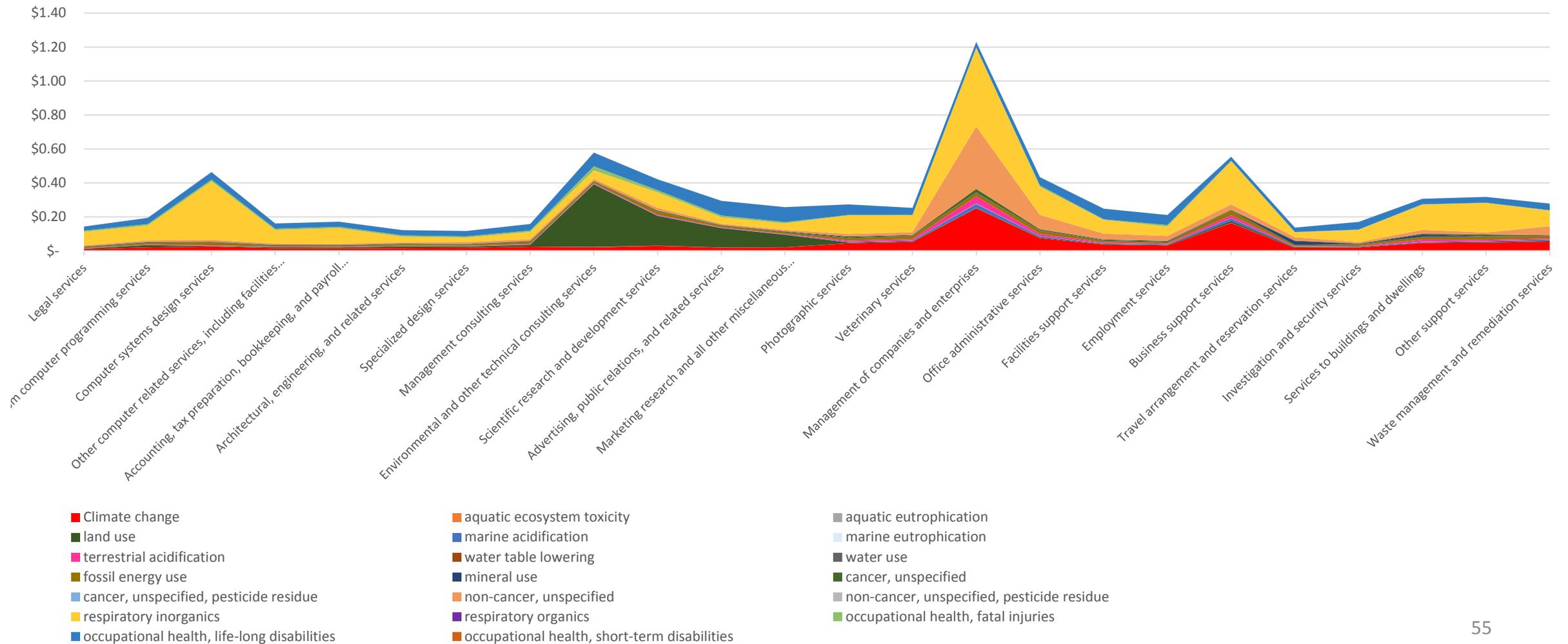
# Information Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



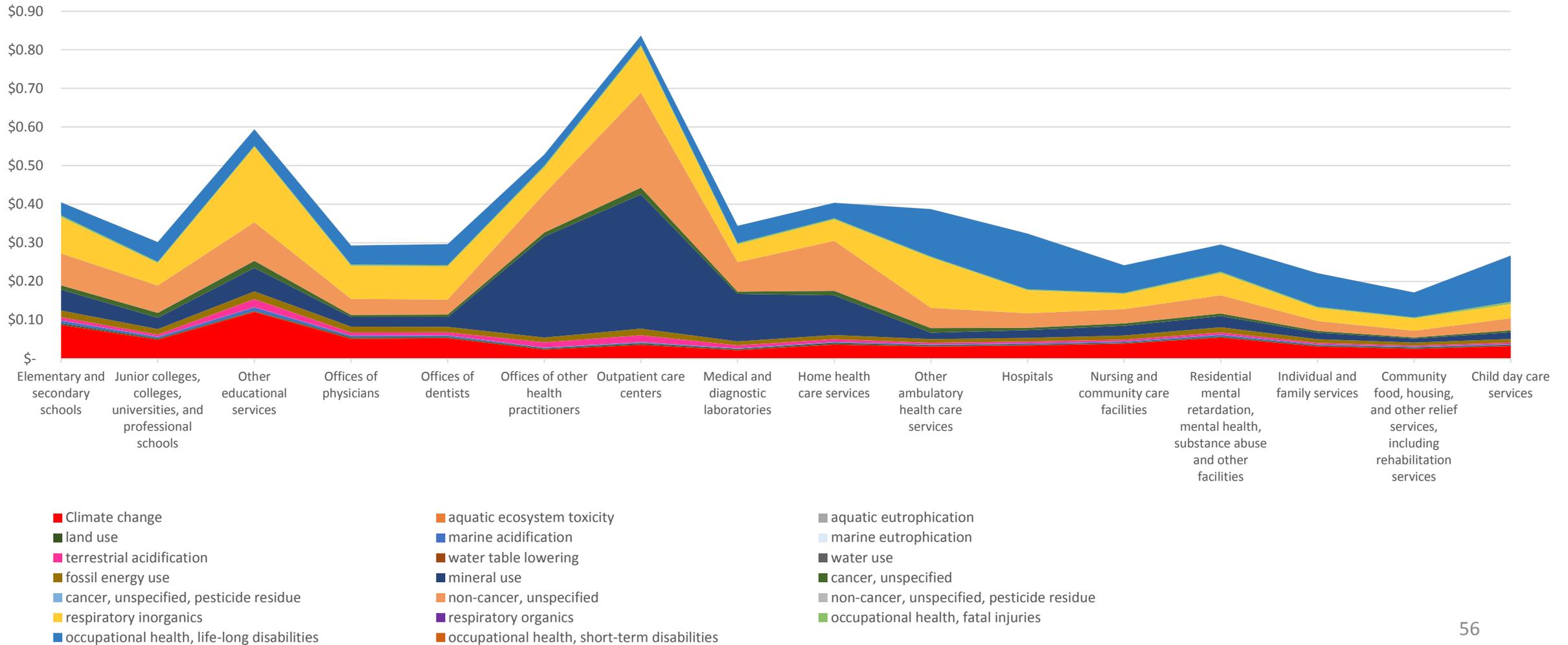
# Finance, Insurance, Real Estate, Etc. Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



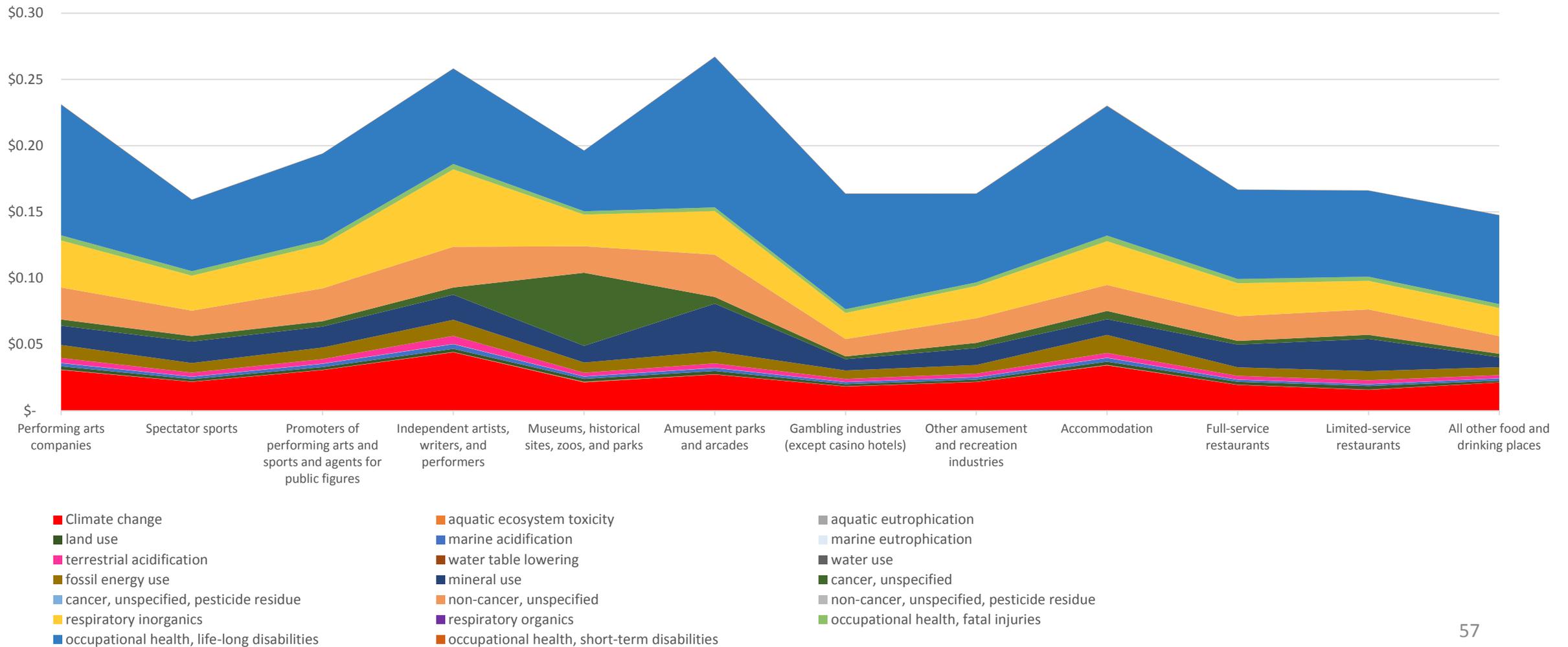
# Professional Services Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



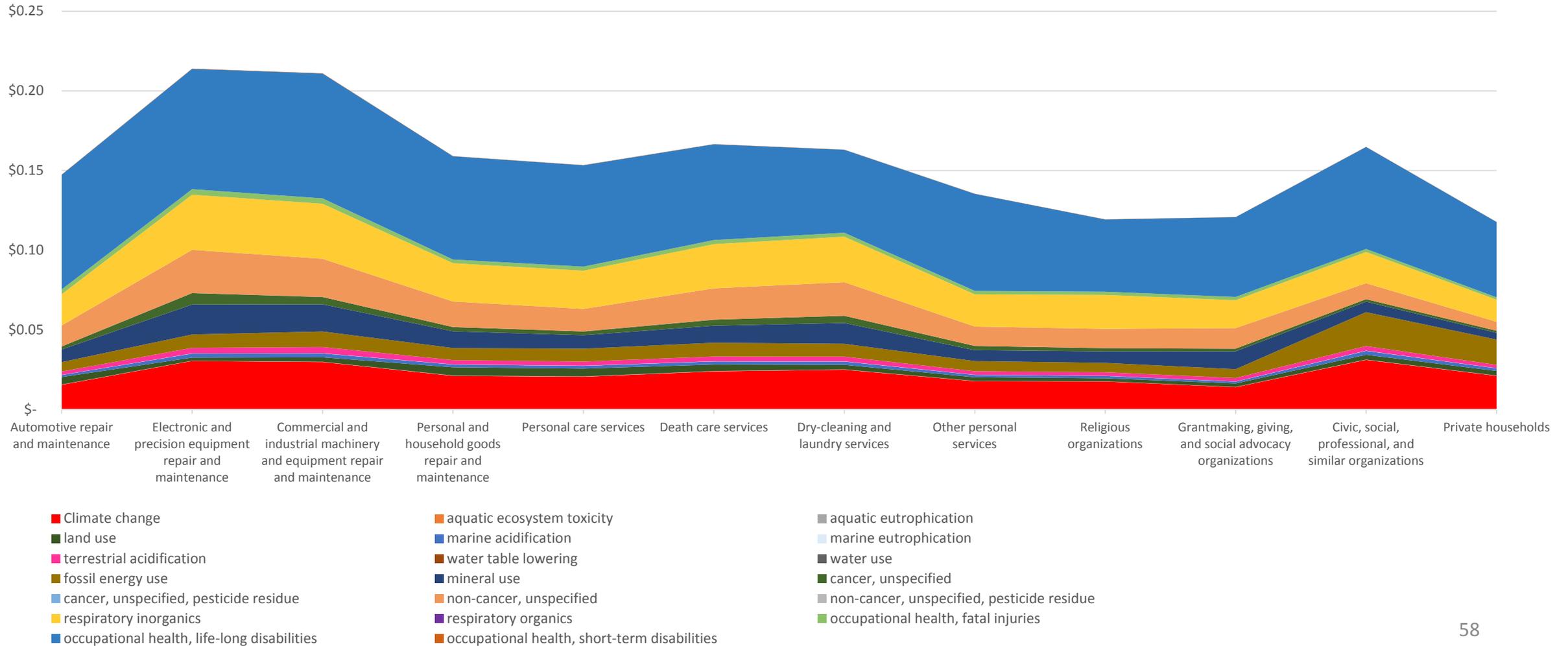
# Educational Services, Health Care, and Social Assistance Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



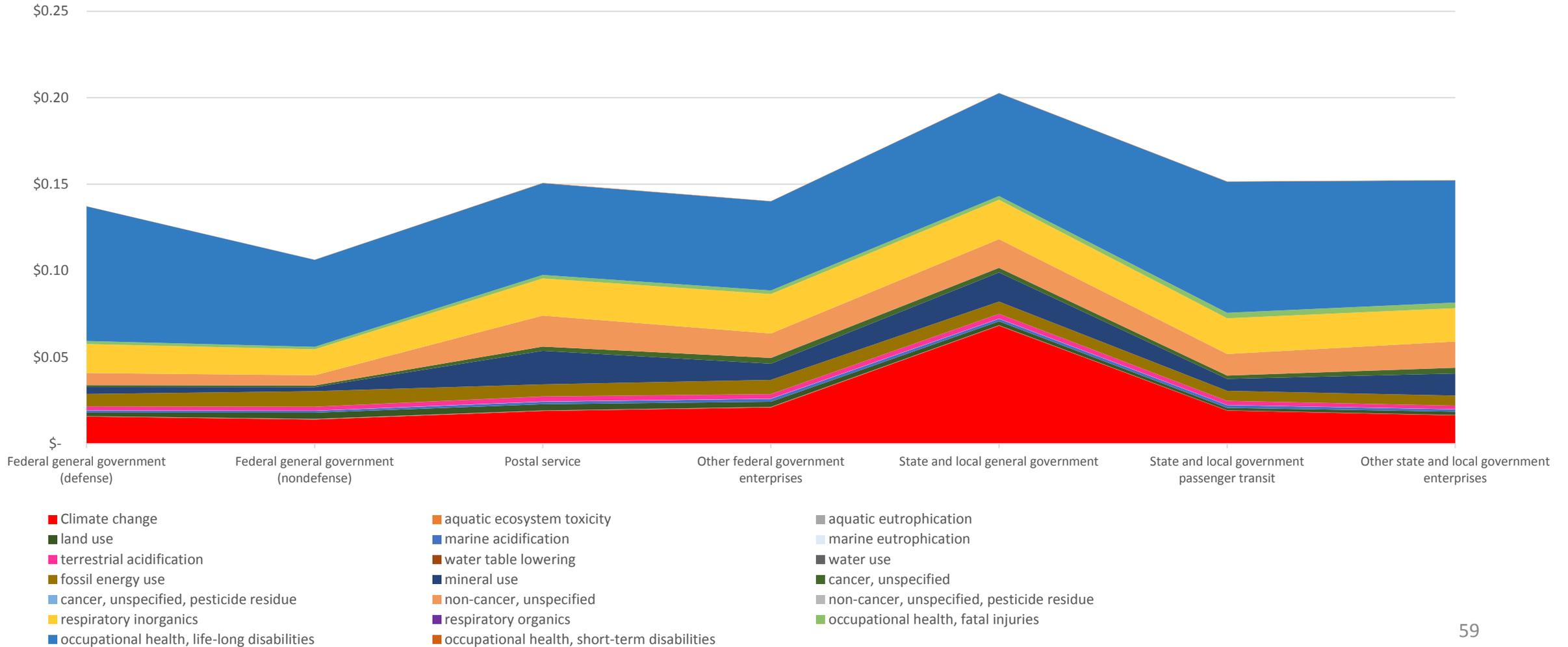
# Arts, Entertainment, Recreation, Accommodation, and Food Services Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



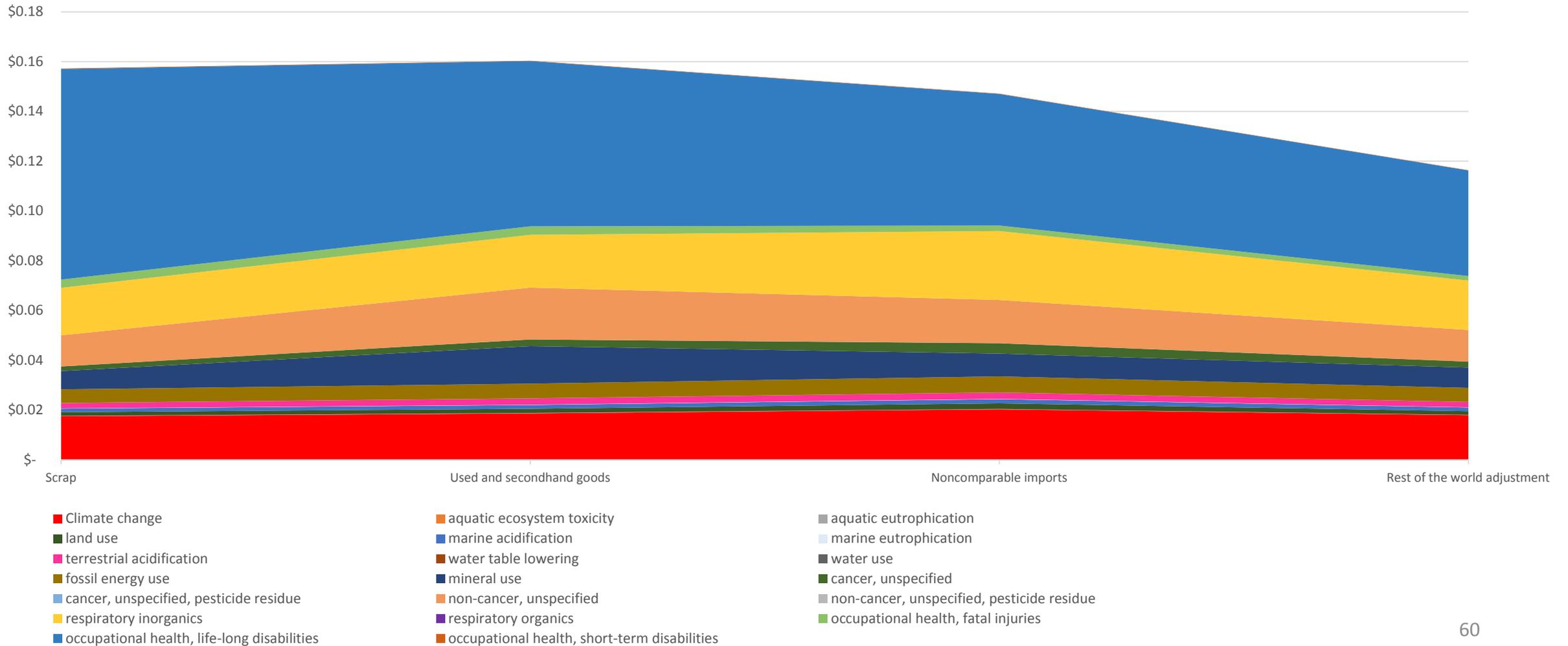
# All Other Non-Government Services Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



# All Government Services Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



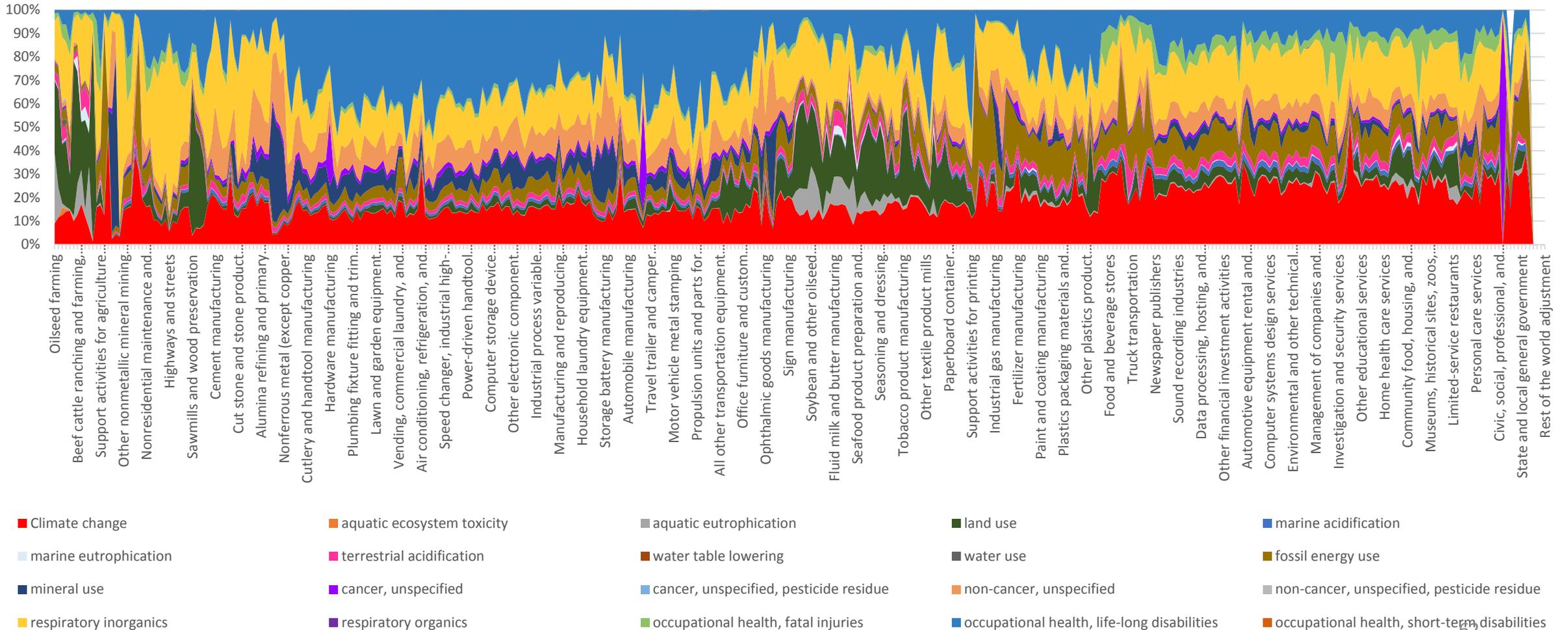
# Scrap, Used & Secondhand Goods, and Rest of World Adjustment Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



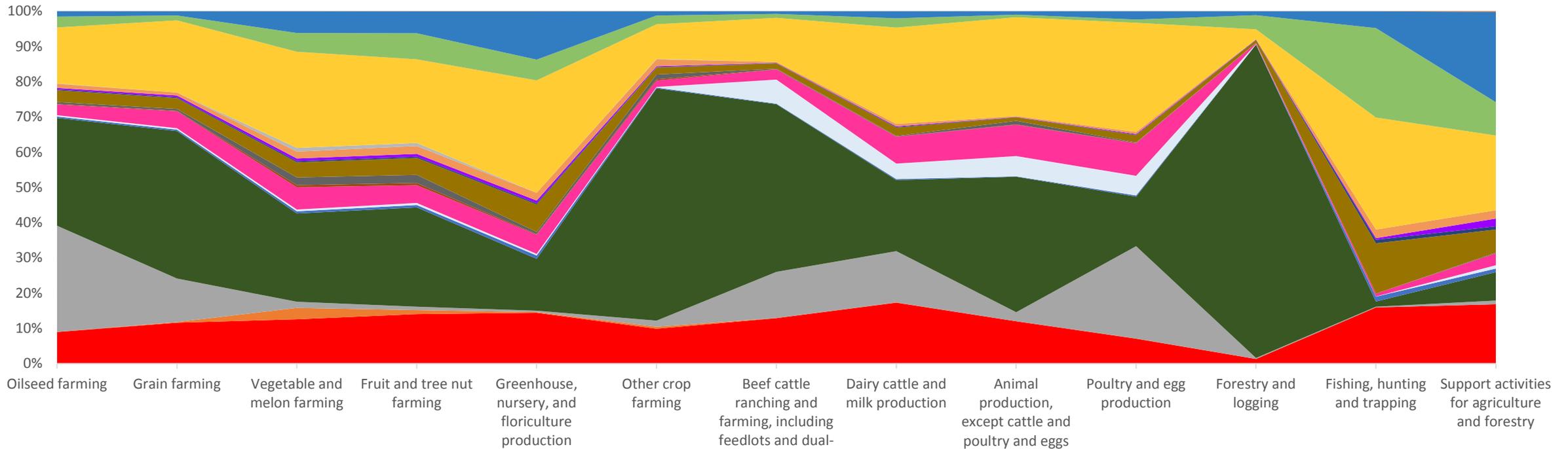
## 2. EnvIO Results

### A. Normalized EnvIO Impact-Per-Spend Valuation Results

# Summary of U.S. Economy Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]

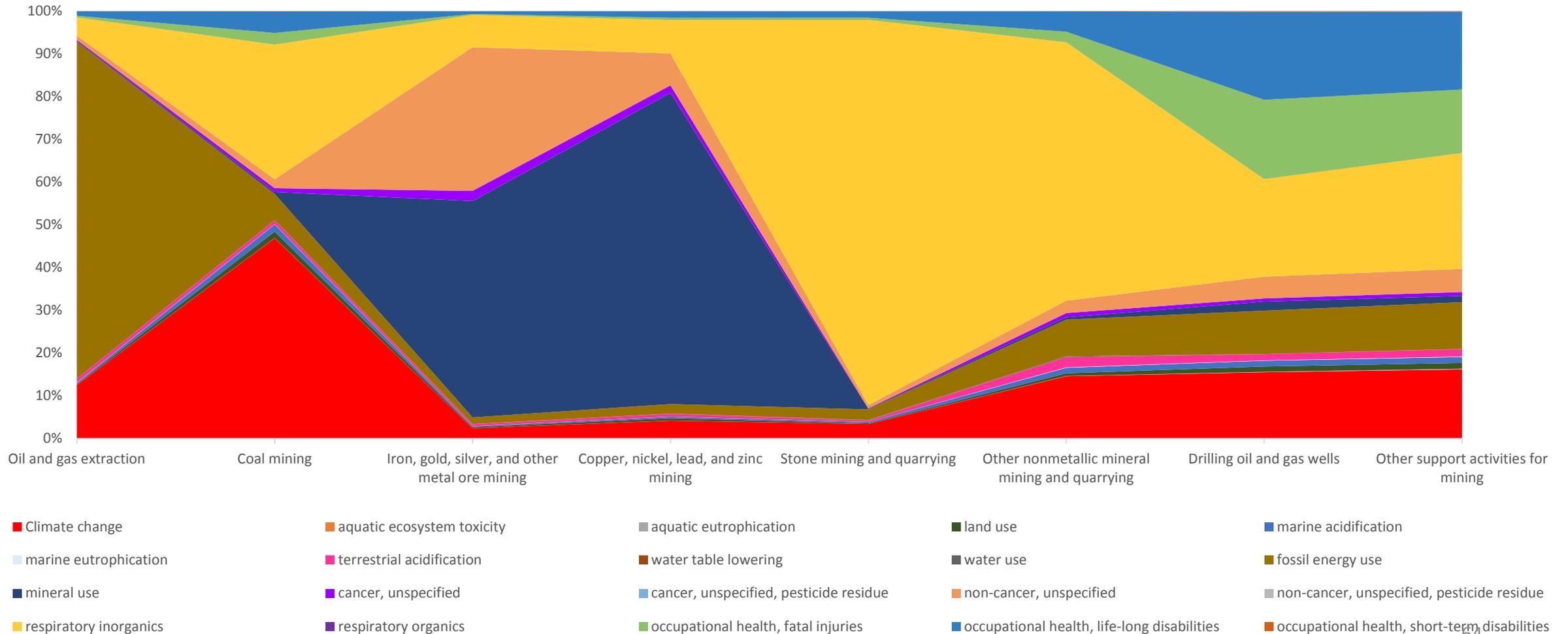


# Agricultural, Forestry, Fish & Hunting Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]

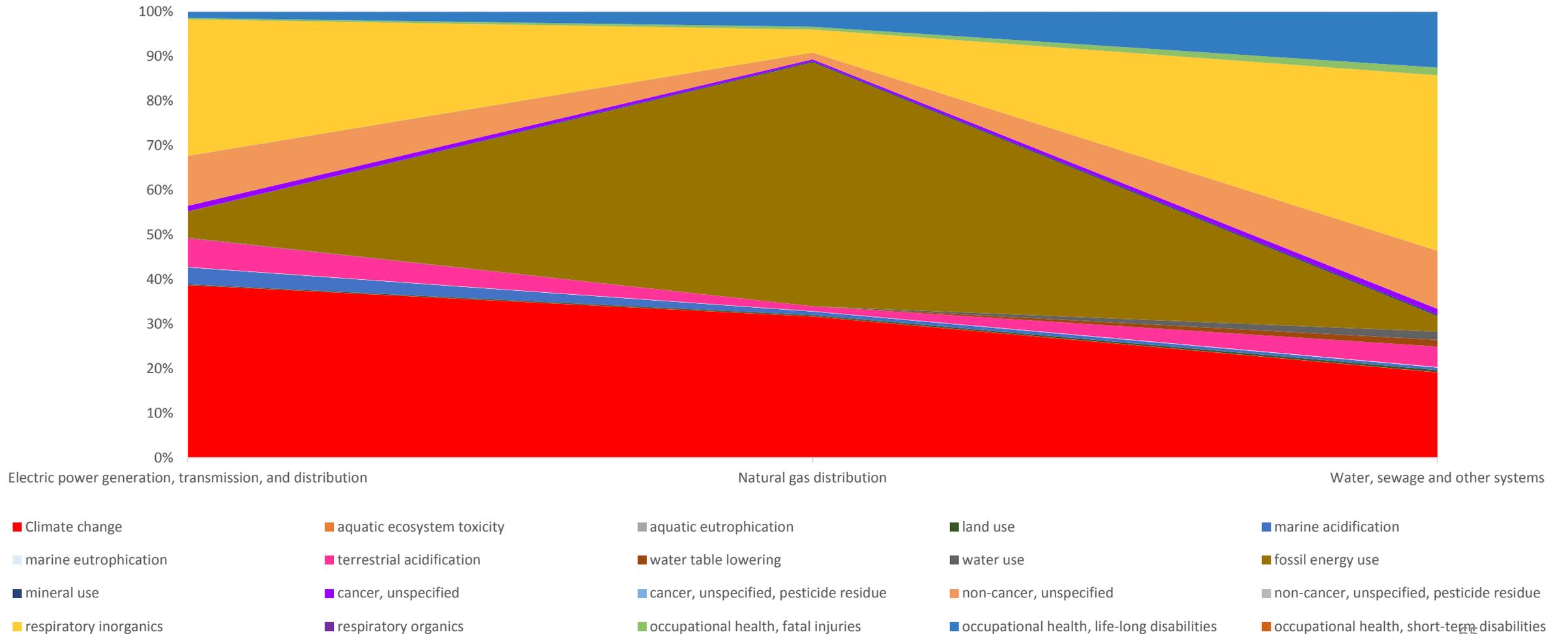


- Climate change
- aquatic ecosystem toxicity
- aquatic eutrophication
- land use
- marine acidification
- marine eutrophication
- terrestrial acidification
- water table lowering
- water use
- fossil energy use
- mineral use
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- non-cancer, unspecified
- non-cancer, unspecified, pesticide residue
- respiratory inorganics
- respiratory organics
- occupational health, fatal injuries
- occupational health, life-long disabilities
- occupational health, short-term disabilities

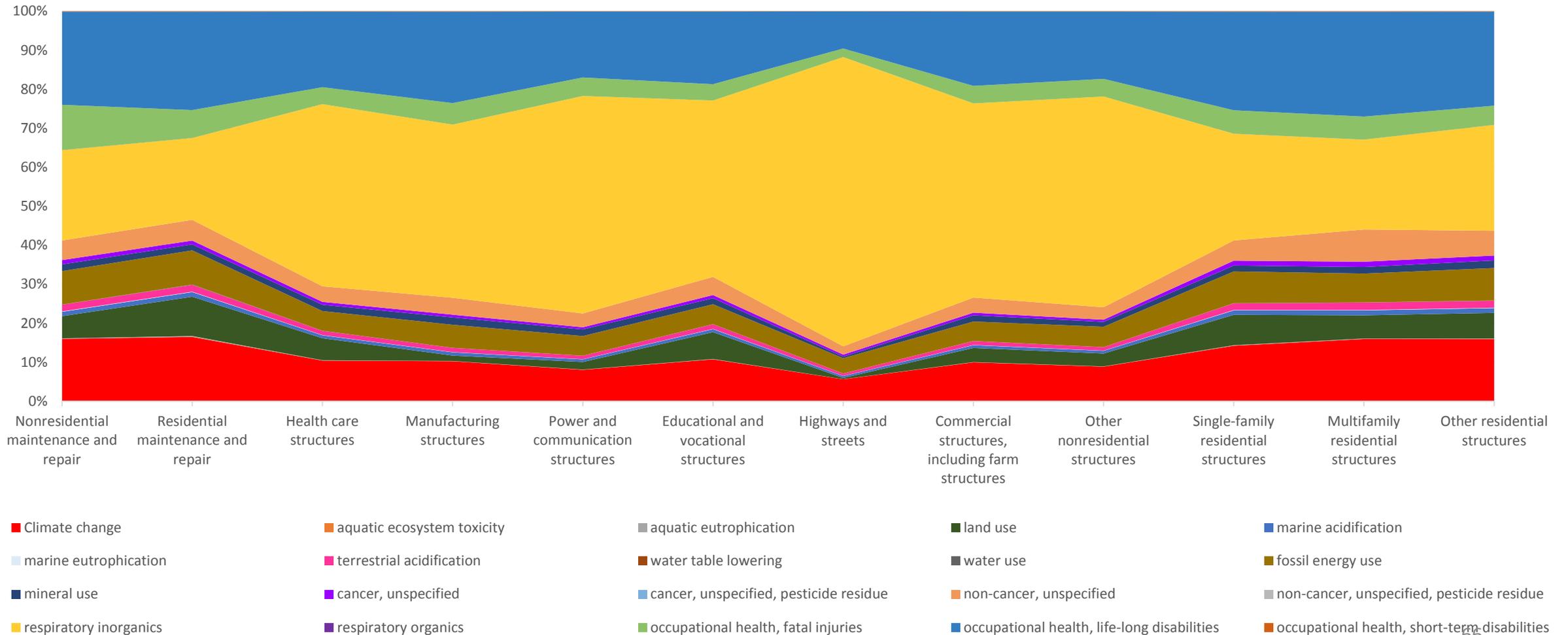
# Mining Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



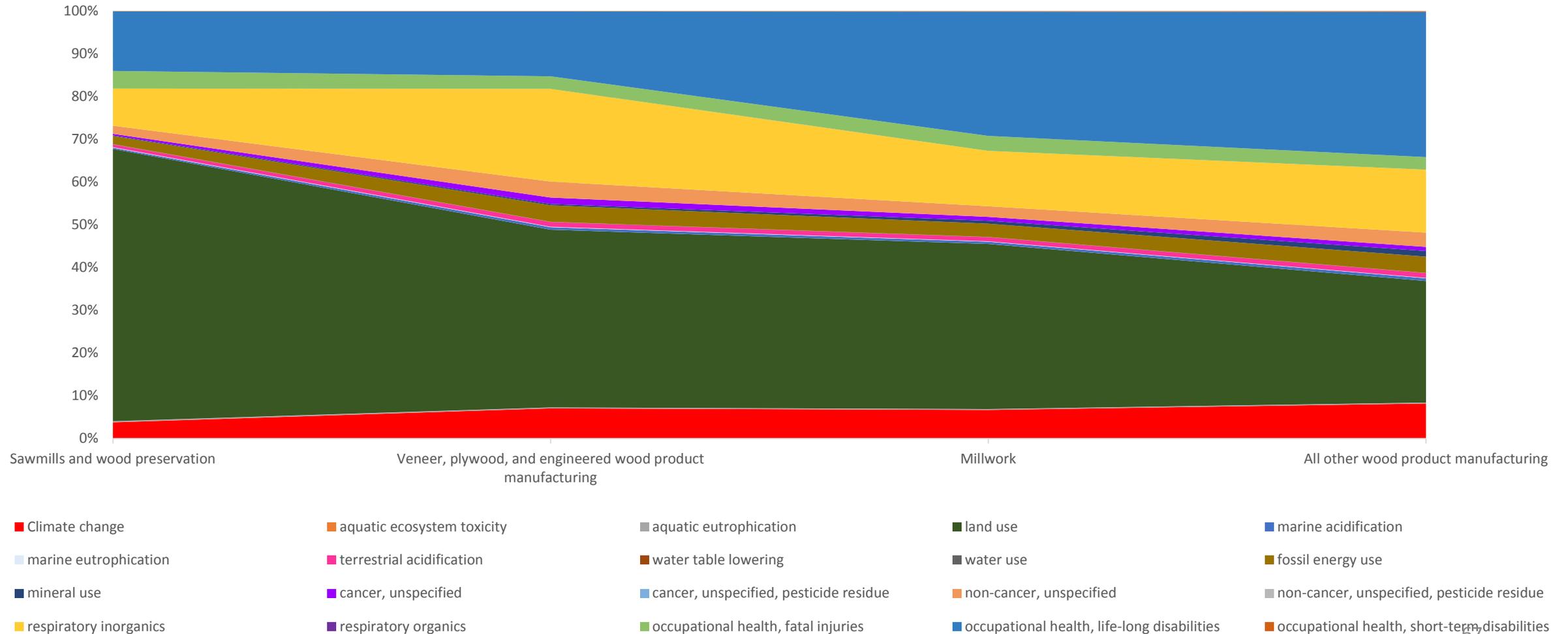
# Utilities Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



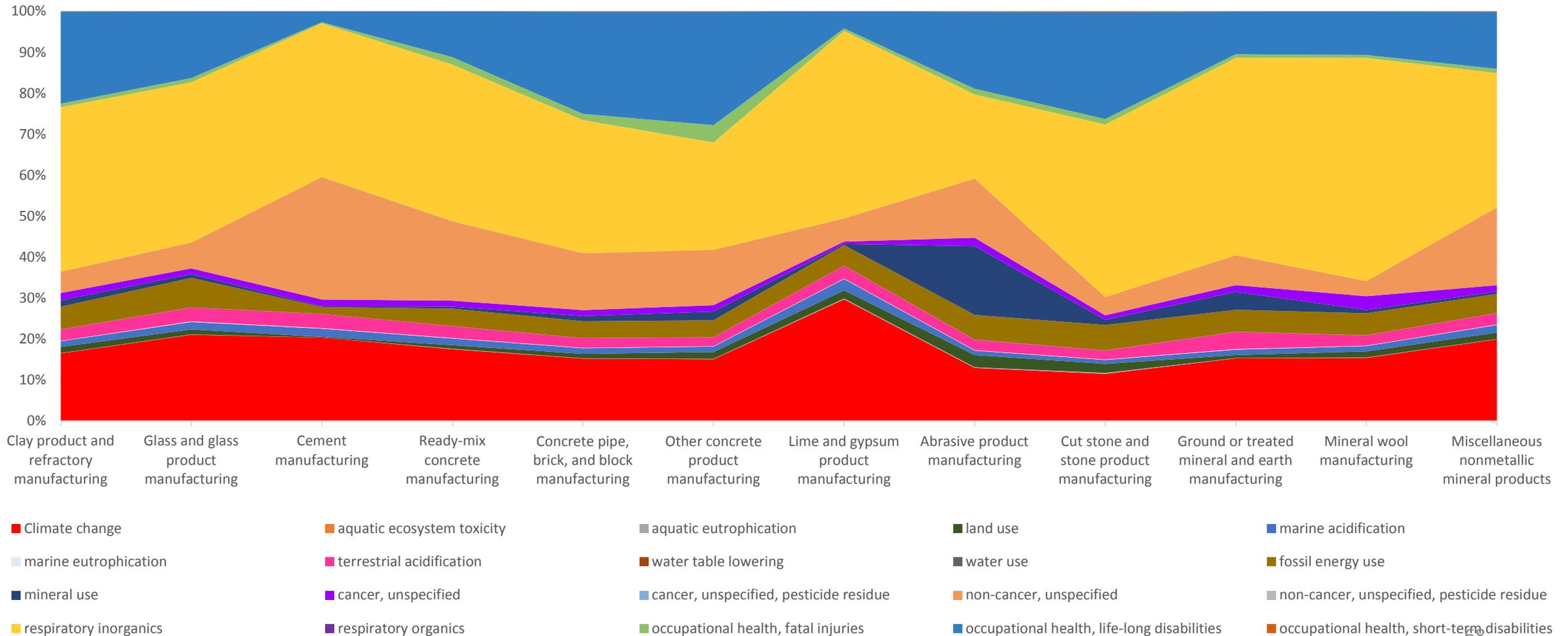
# Construction Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



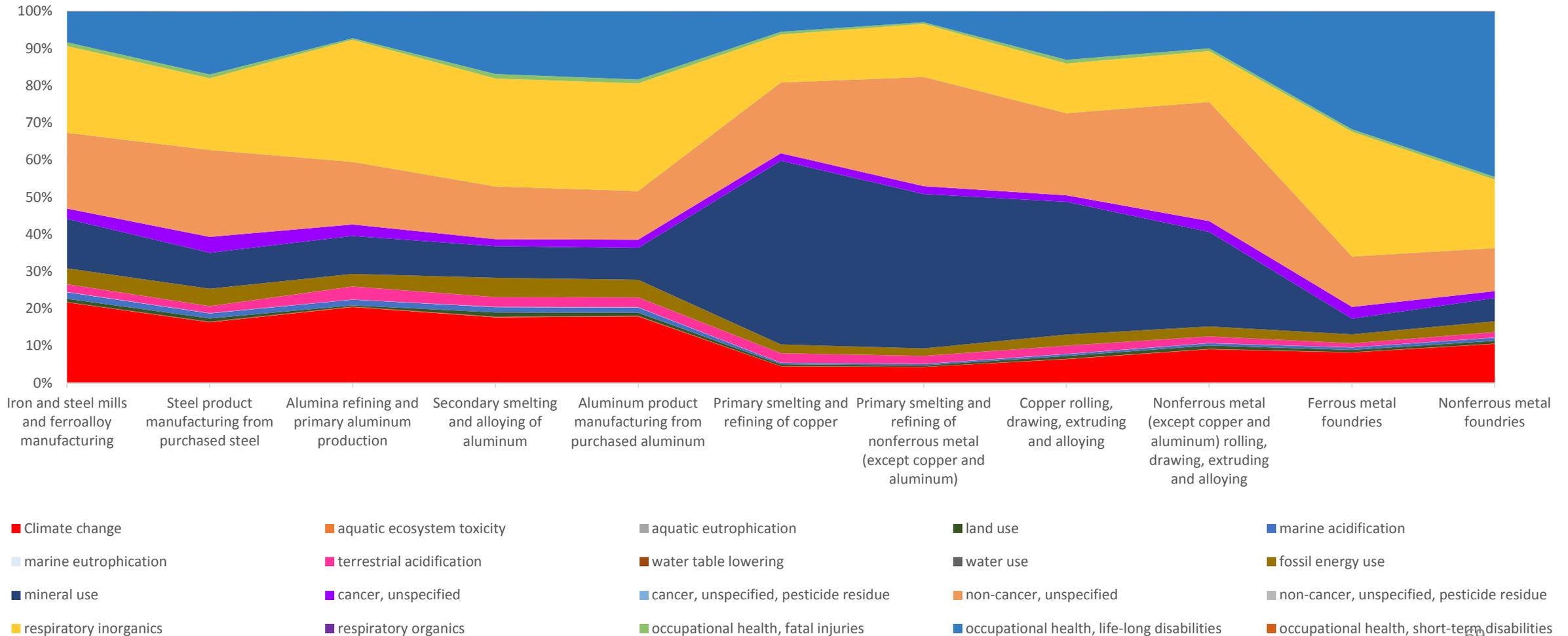
# Wood Products Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



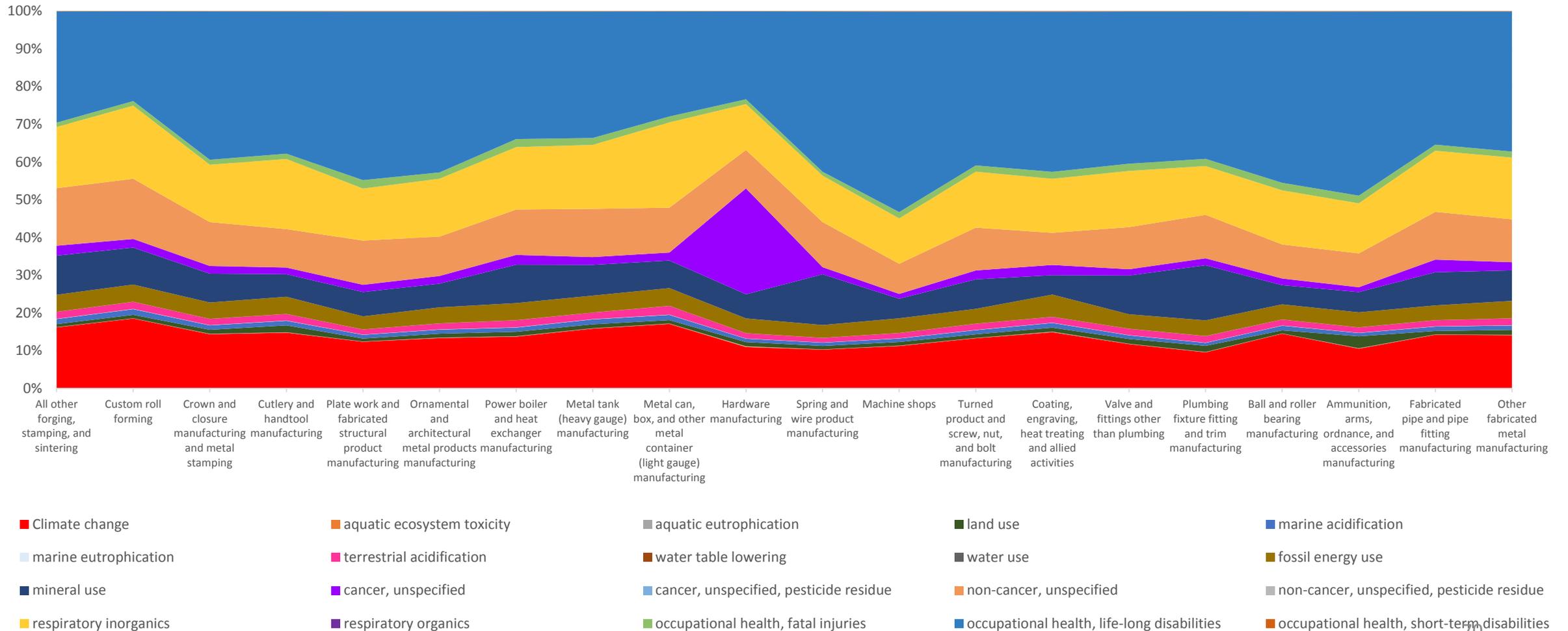
# Nonmetallic Mineral Products Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



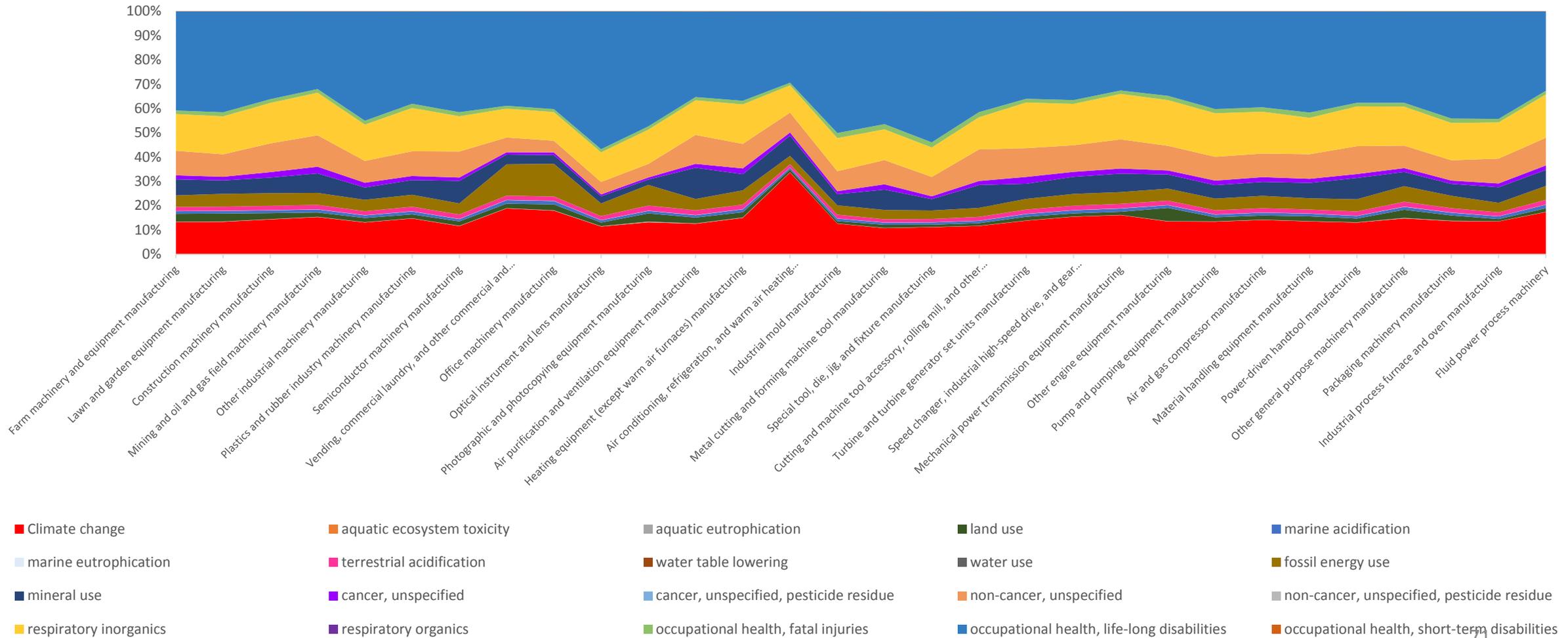
# Primary Metals Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



# Fabricated Metal Products Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]

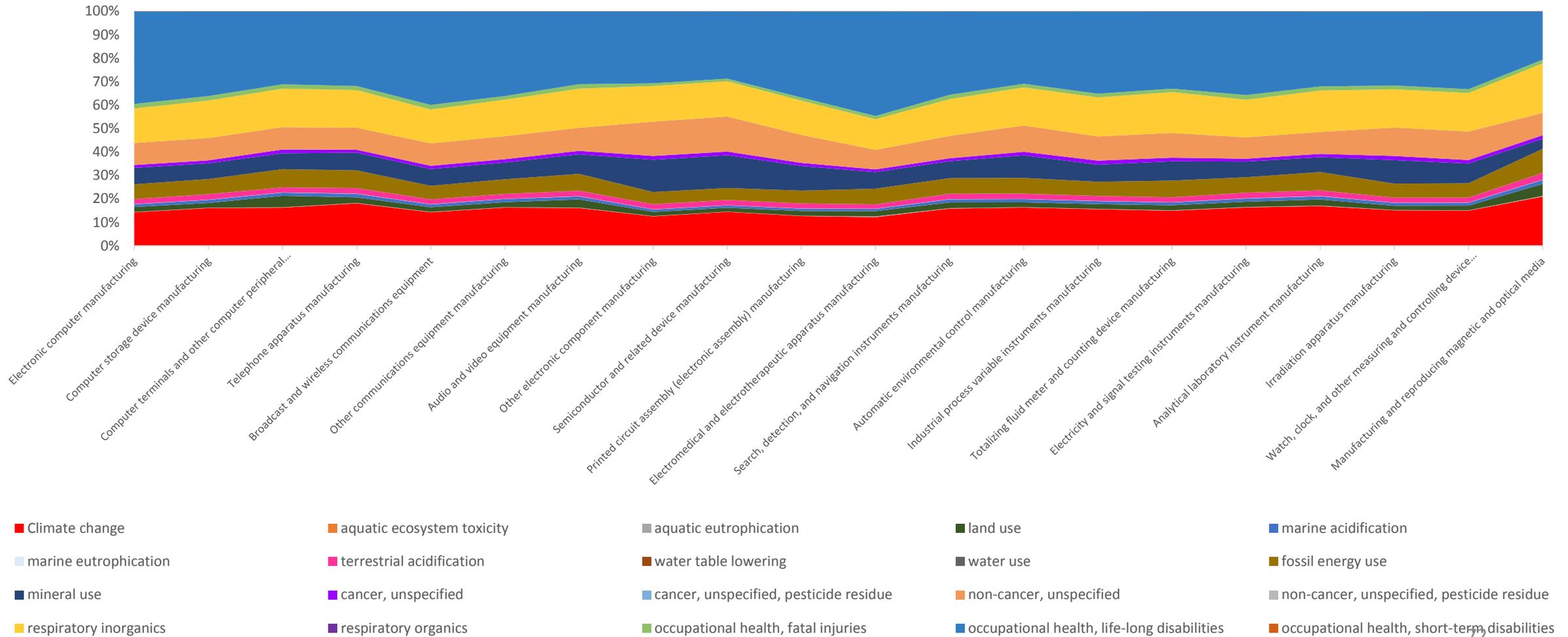


# Machinery Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]

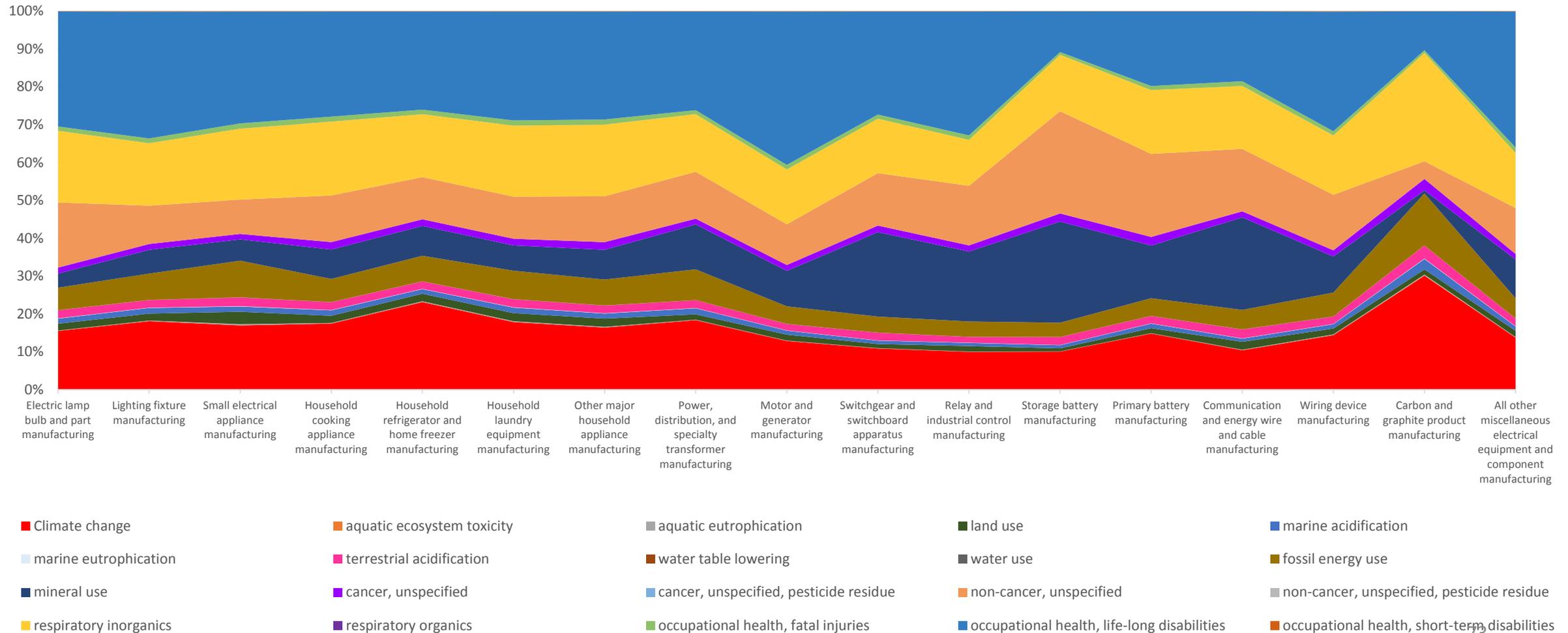


# Computer and Electronic Products Impact Valuation Results

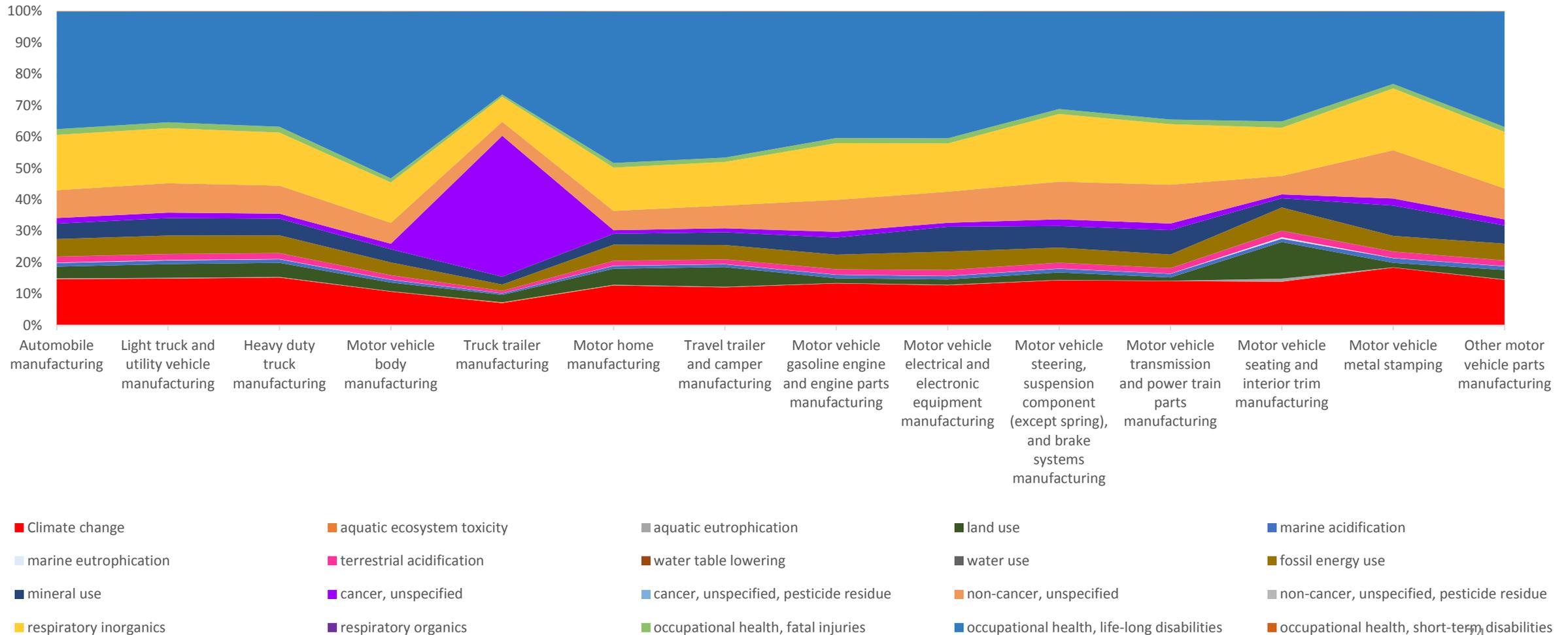
## [Total Impacts (USD 2014) per USD2007 of spend]



# Electrical Equipment, Appliances, and Components Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]

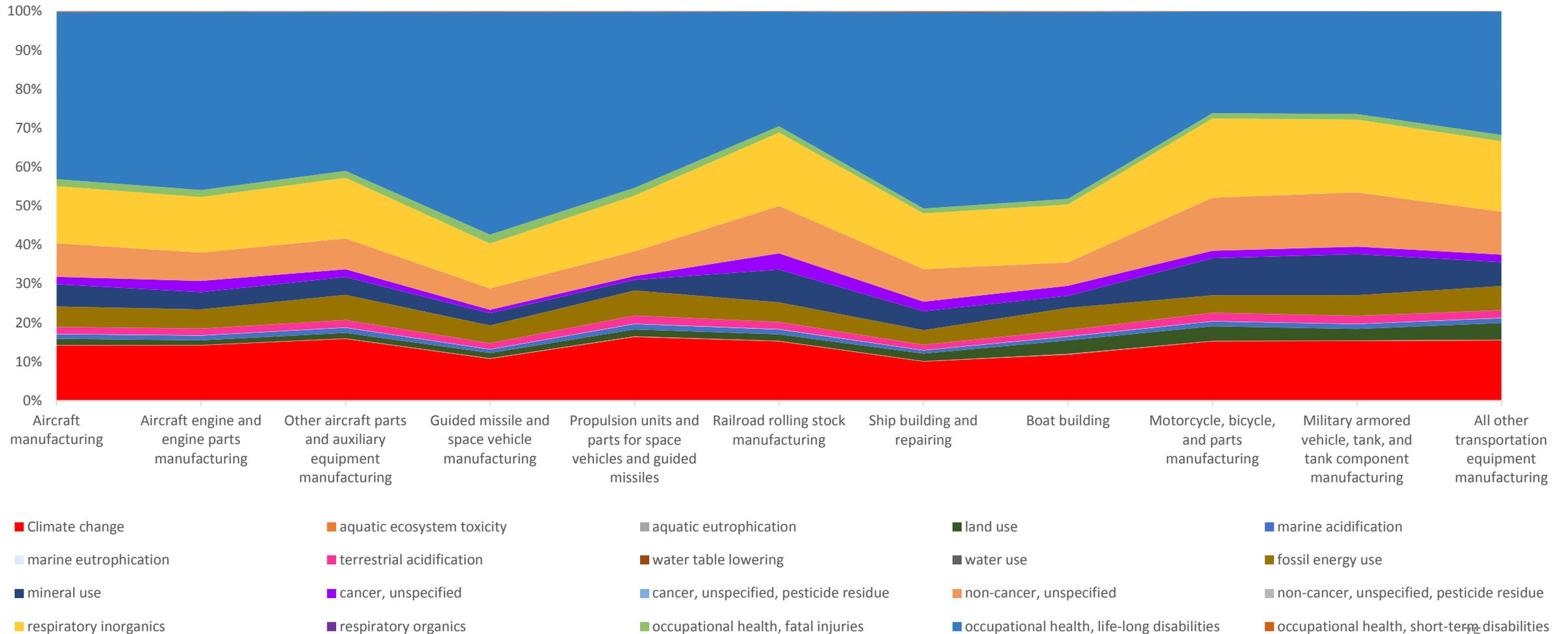


# Motor Vehicles Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]

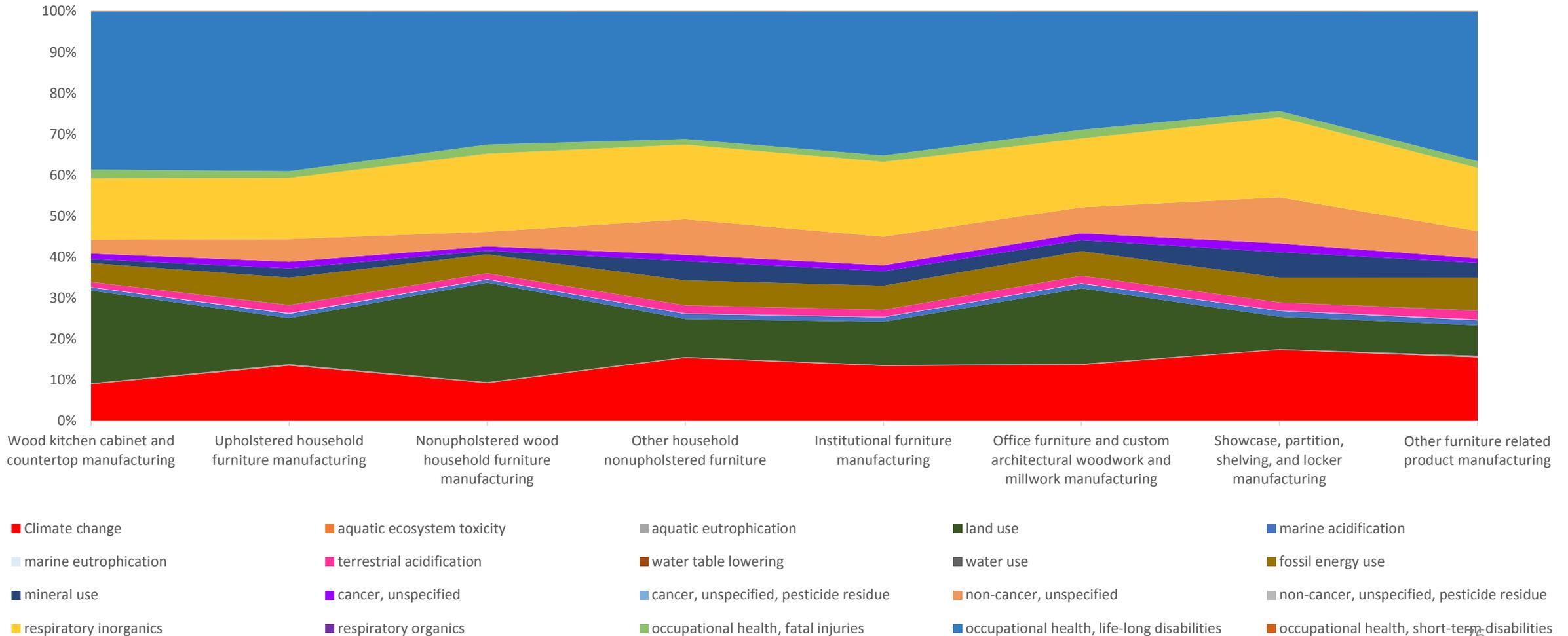


# Other Transportation Equipment Impact Valuation Results

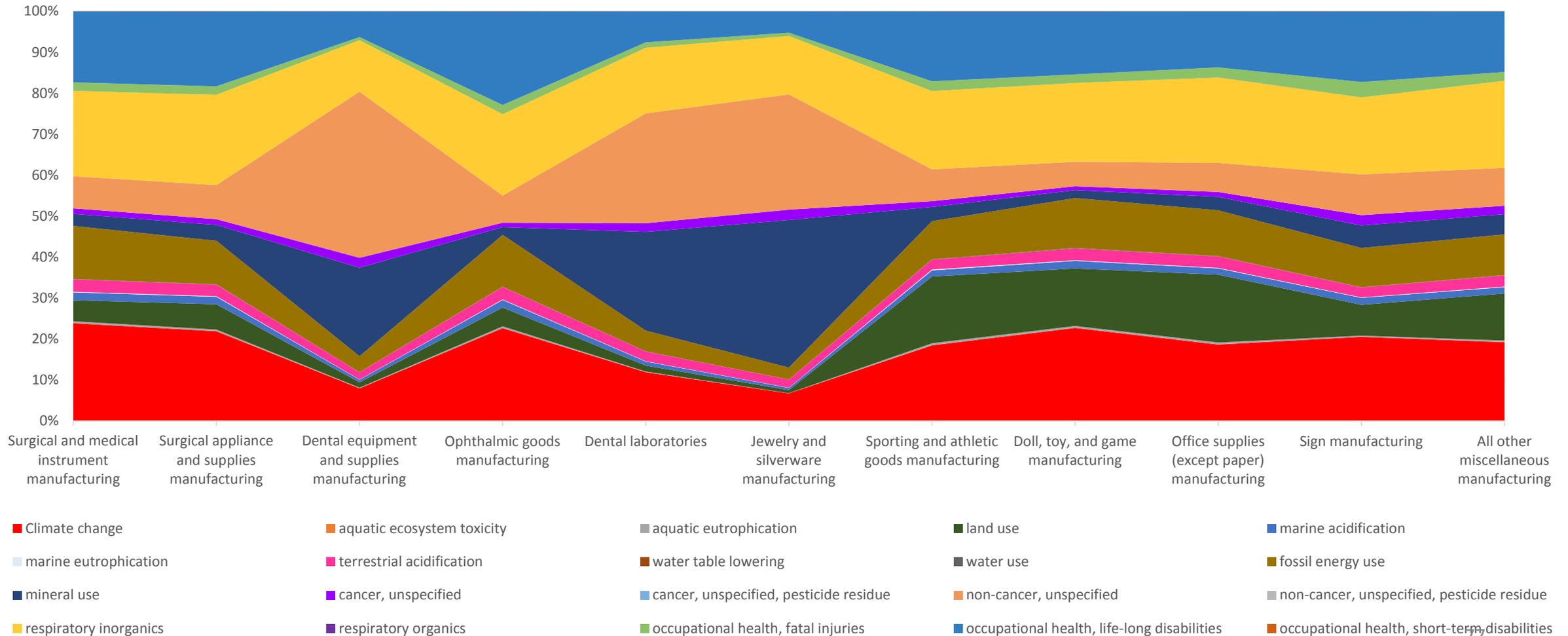
## [Total Impacts (USD 2014) per USD2007 of spend]



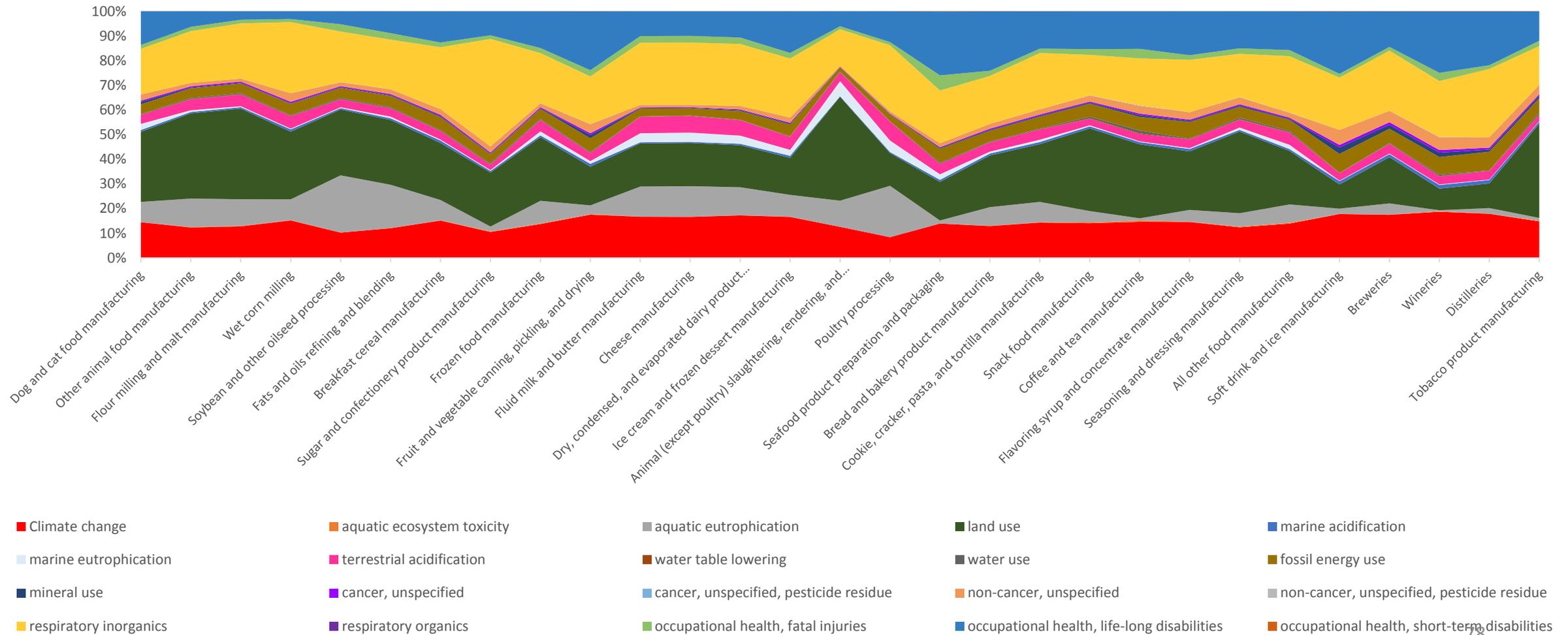
# Furniture and Related Products Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



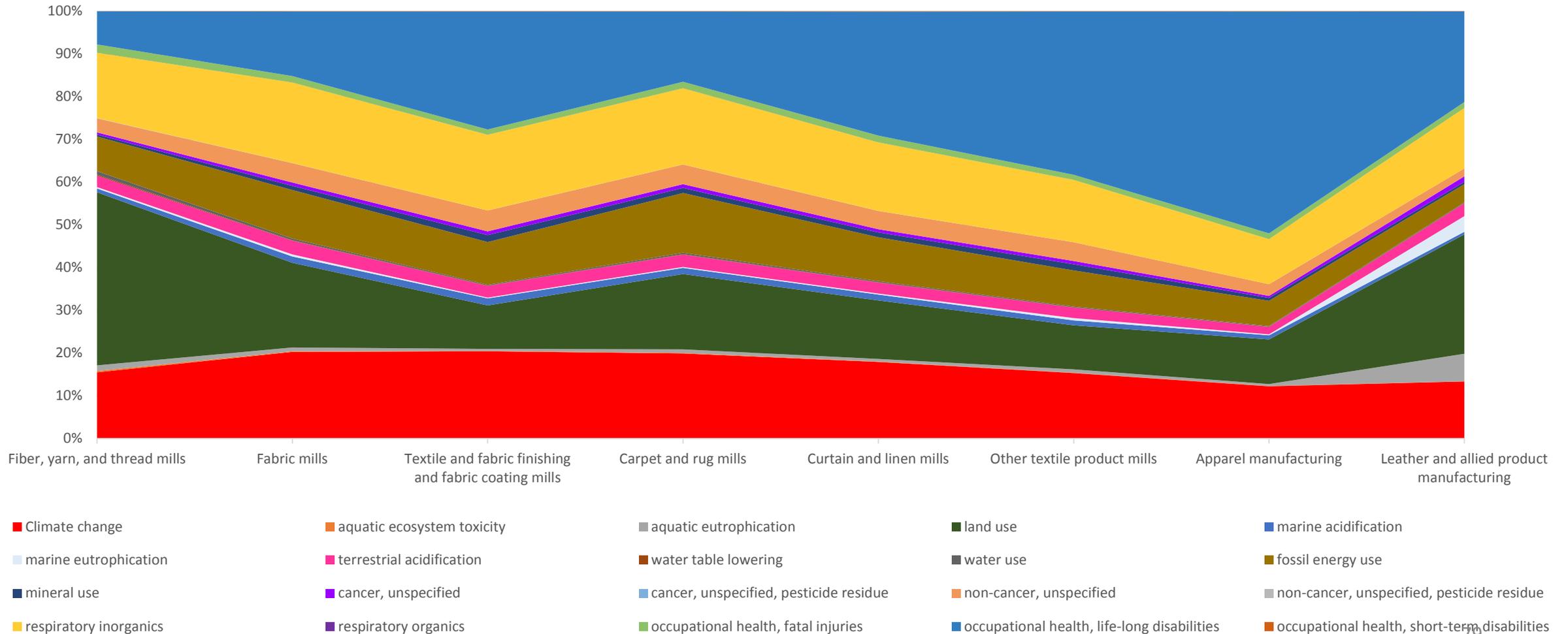
# Misc. Manufacturing Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



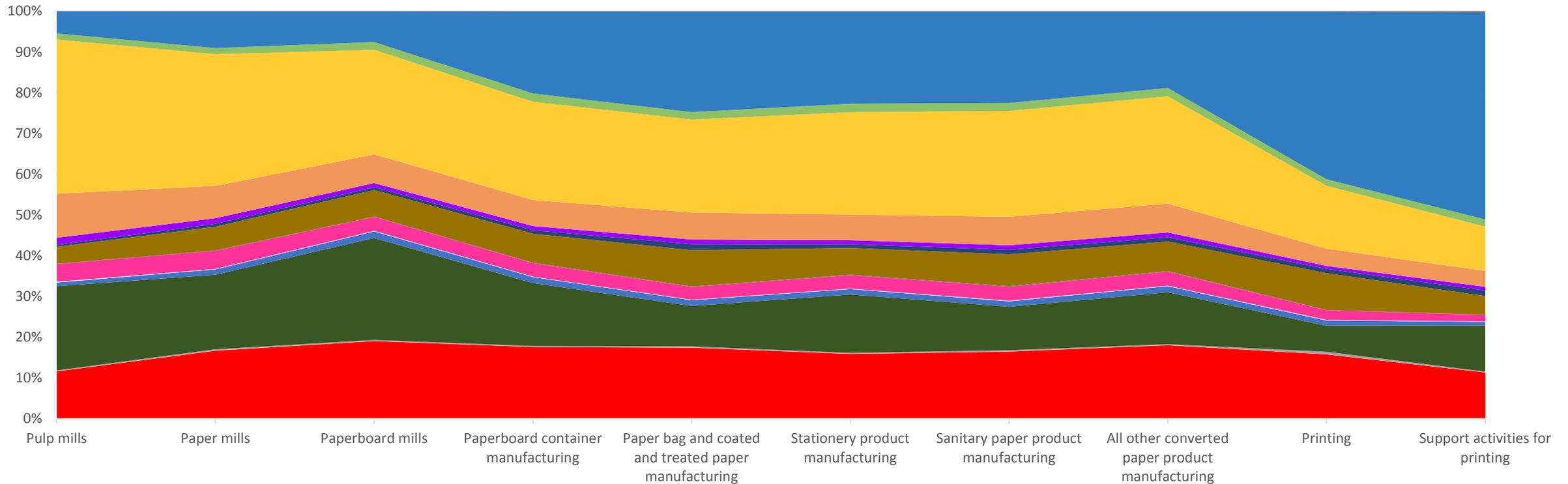
# Food & Beverage and Tobacco Products Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



# Textiles, Apparel, Leather, and Allied Products Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]

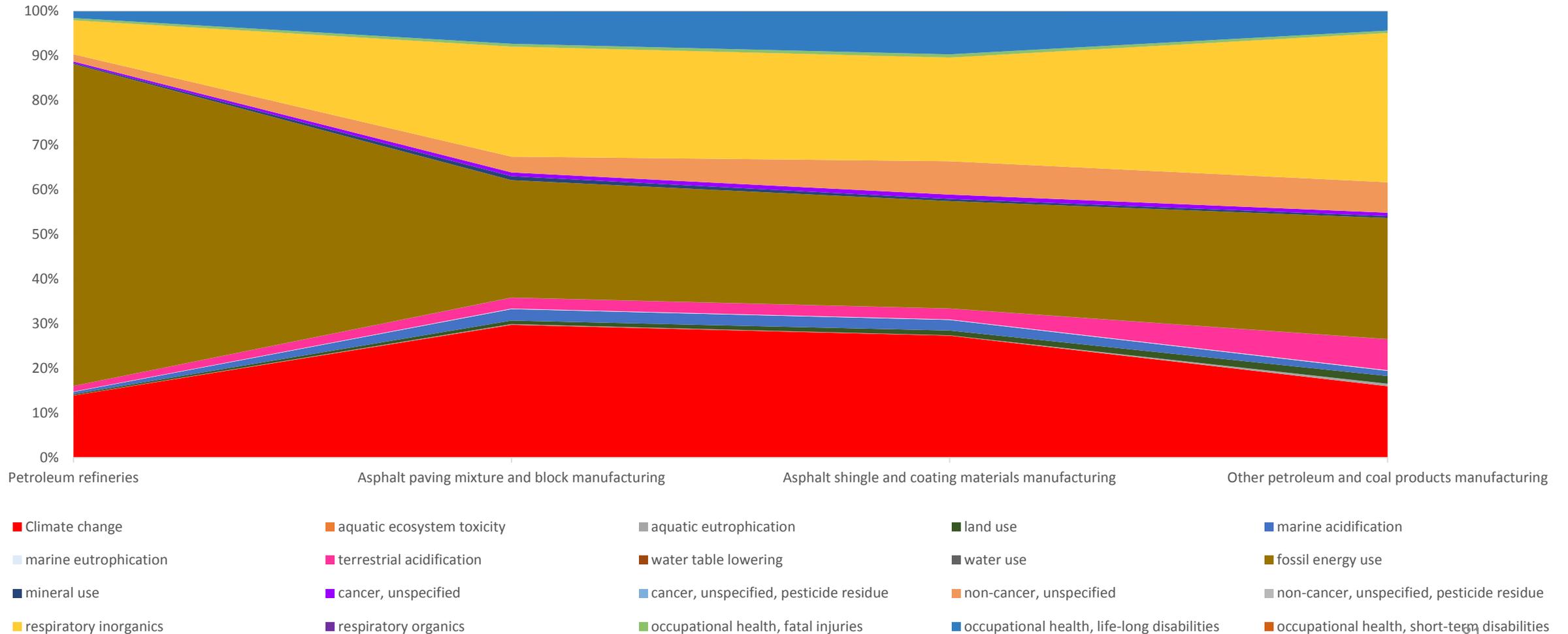


# Paper Products and Printing Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]

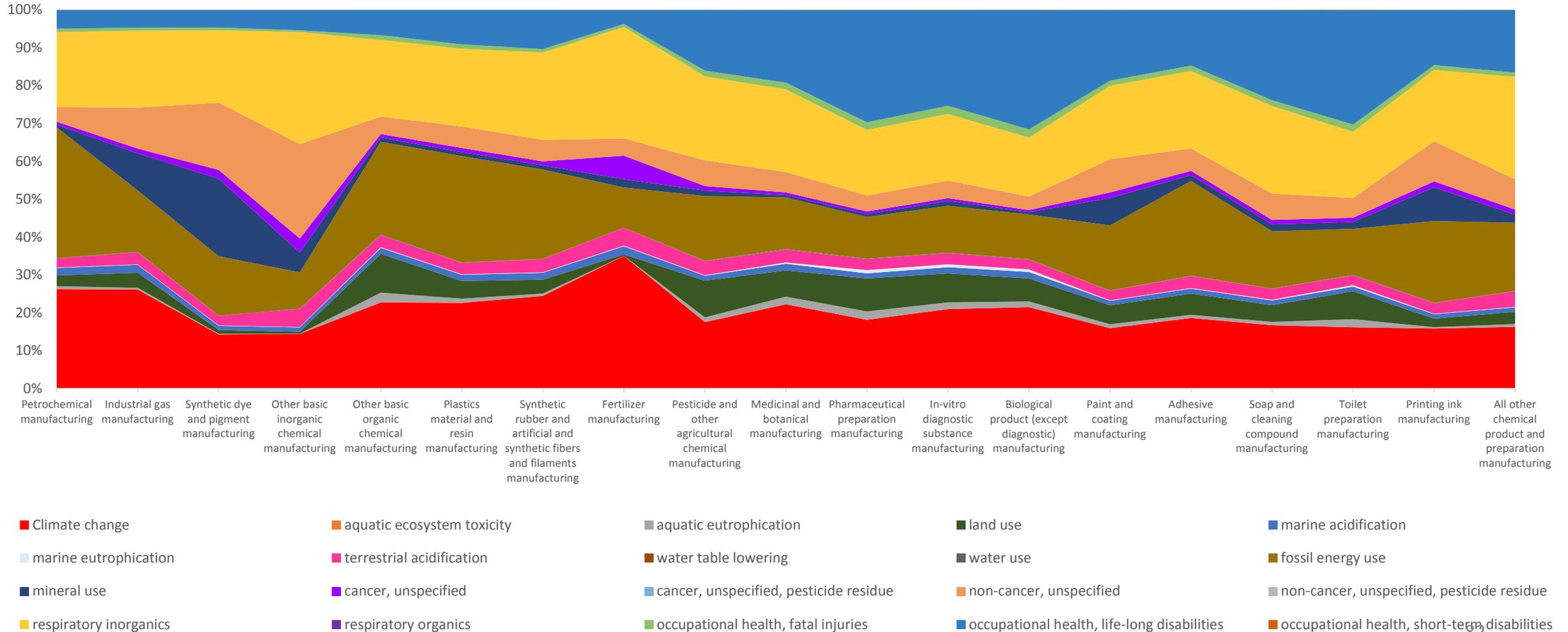


- Climate change
- aquatic ecosystem toxicity
- aquatic eutrophication
- land use
- marine acidification
- marine eutrophication
- terrestrial acidification
- water table lowering
- water use
- fossil energy use
- mineral use
- cancer, unspecified
- cancer, unspecified, pesticide residue
- non-cancer, unspecified
- non-cancer, unspecified, pesticide residue
- respiratory inorganics
- respiratory organics
- occupational health, fatal injuries
- occupational health, life-long disabilities
- occupational health, short-term disabilities

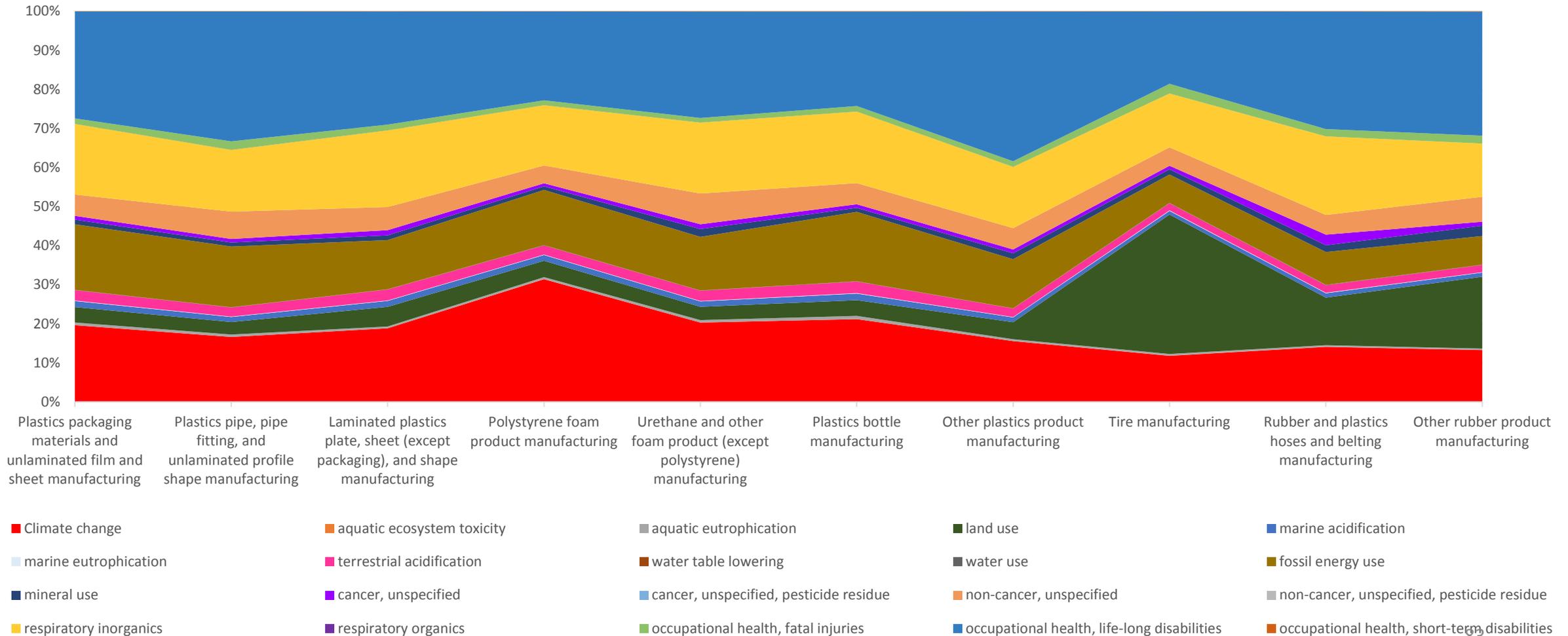
# Petroleum and Coal Products Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



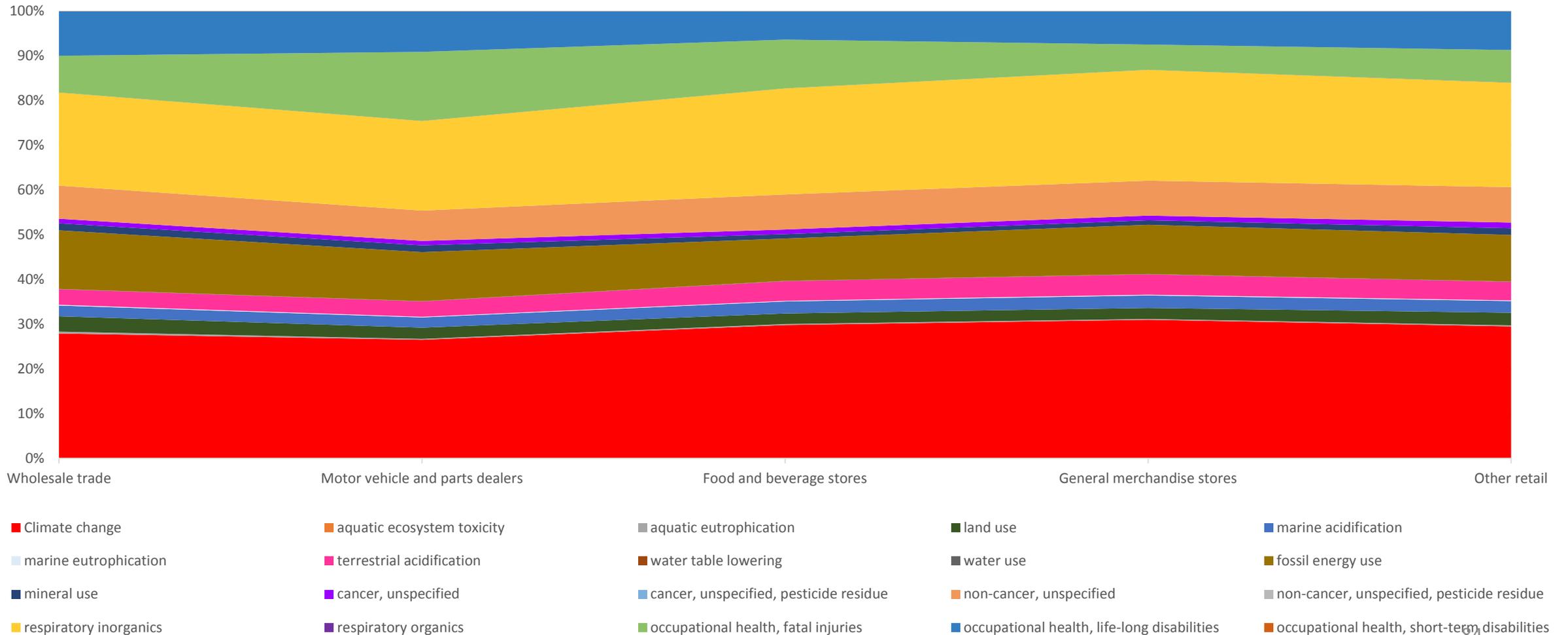
# Chemical Products Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



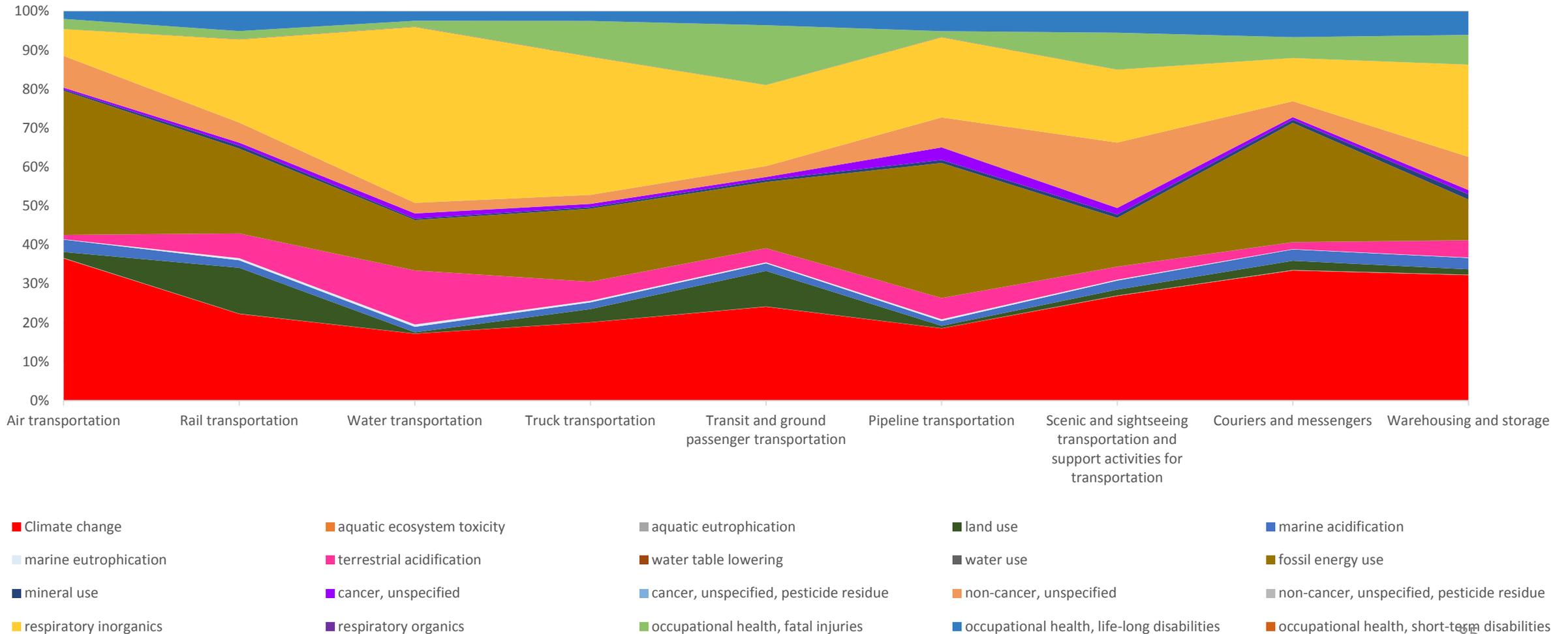
# Plastics and Rubber Products Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



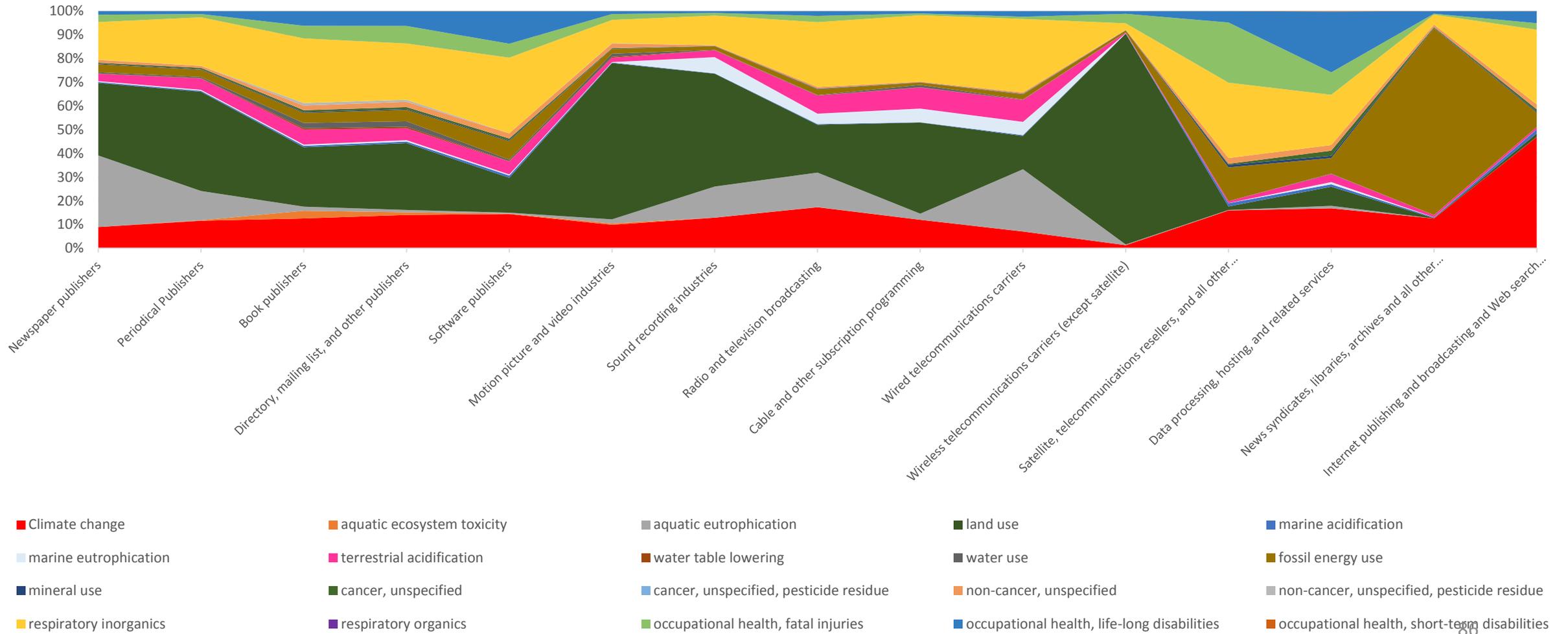
# Wholesale and Retail Trade Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



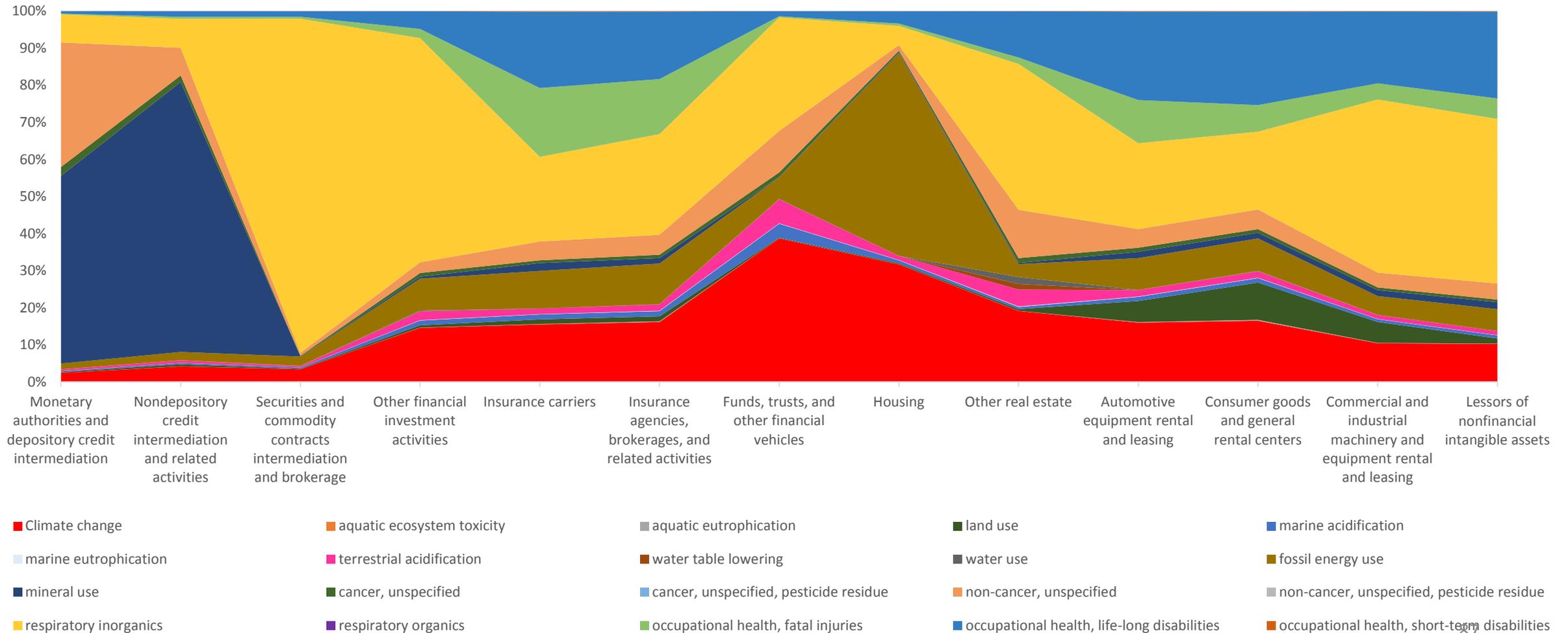
# Transportation and Warehousing Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



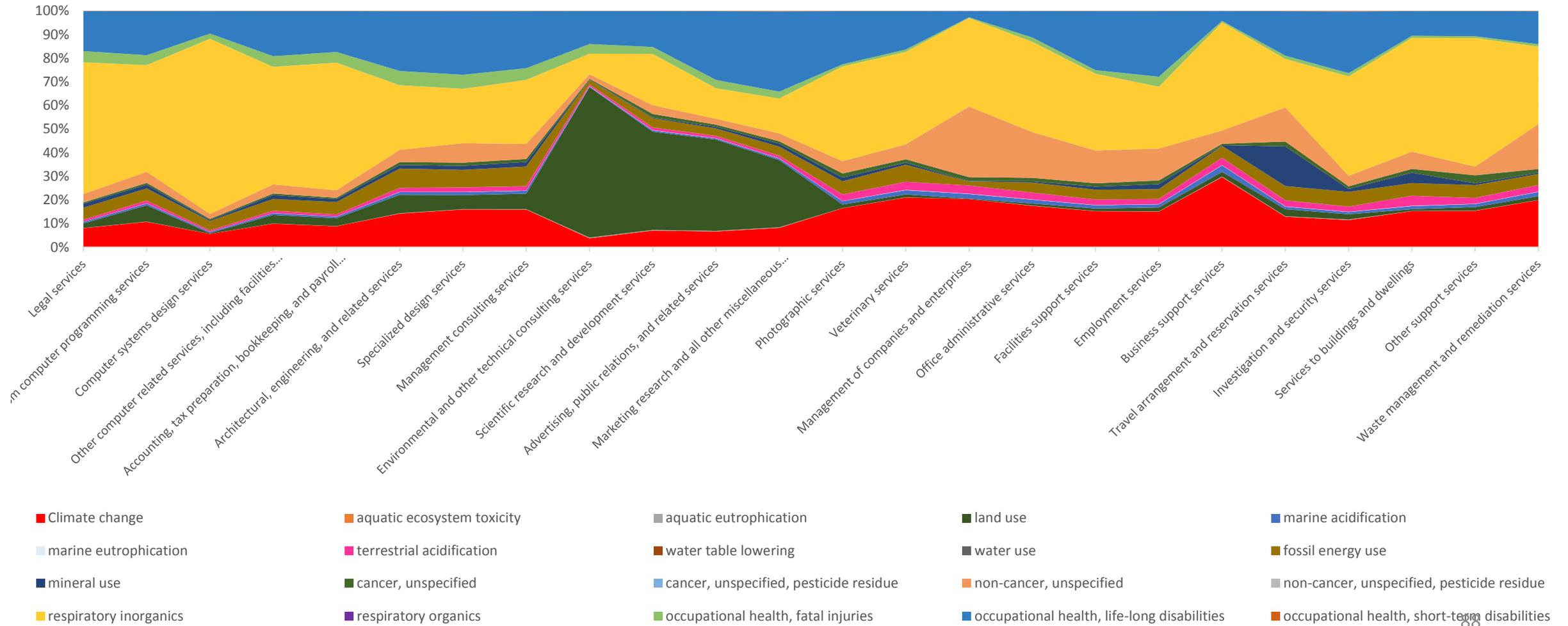
# Information Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



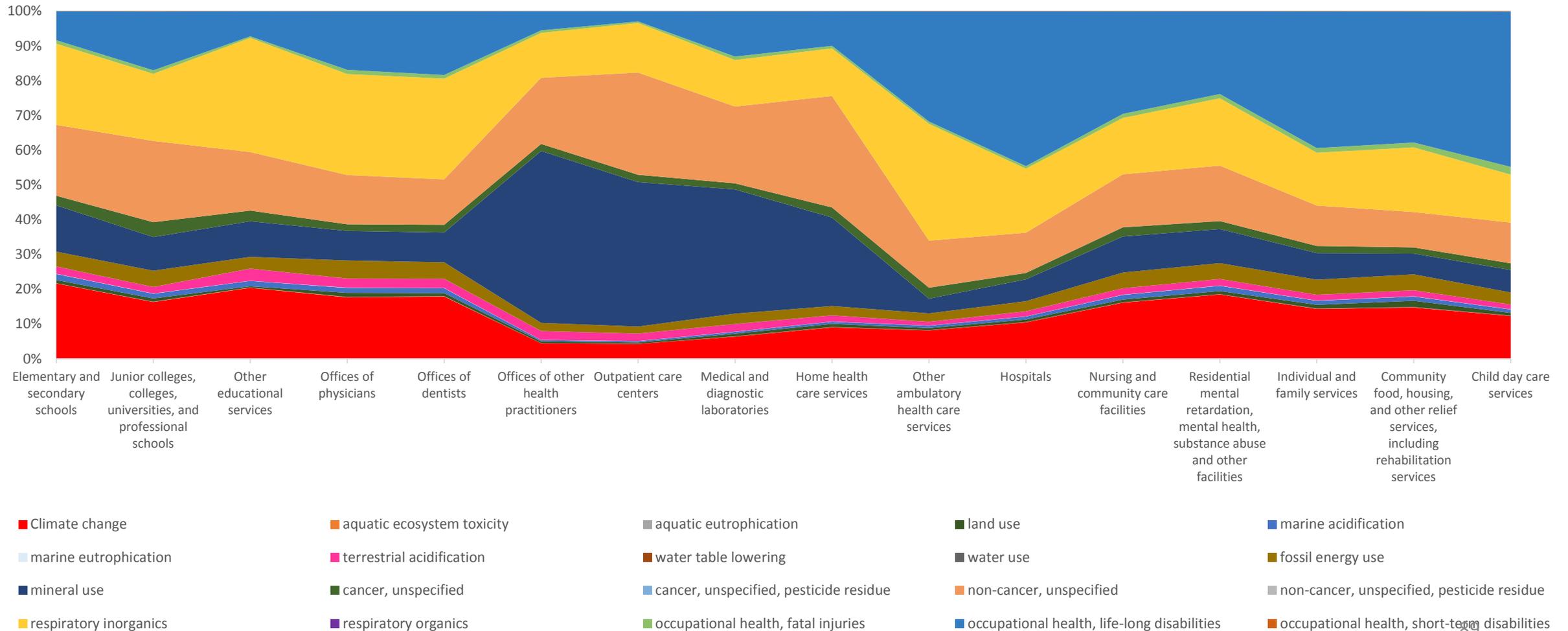
# Finance, Insurance, Real Estate, Etc. Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



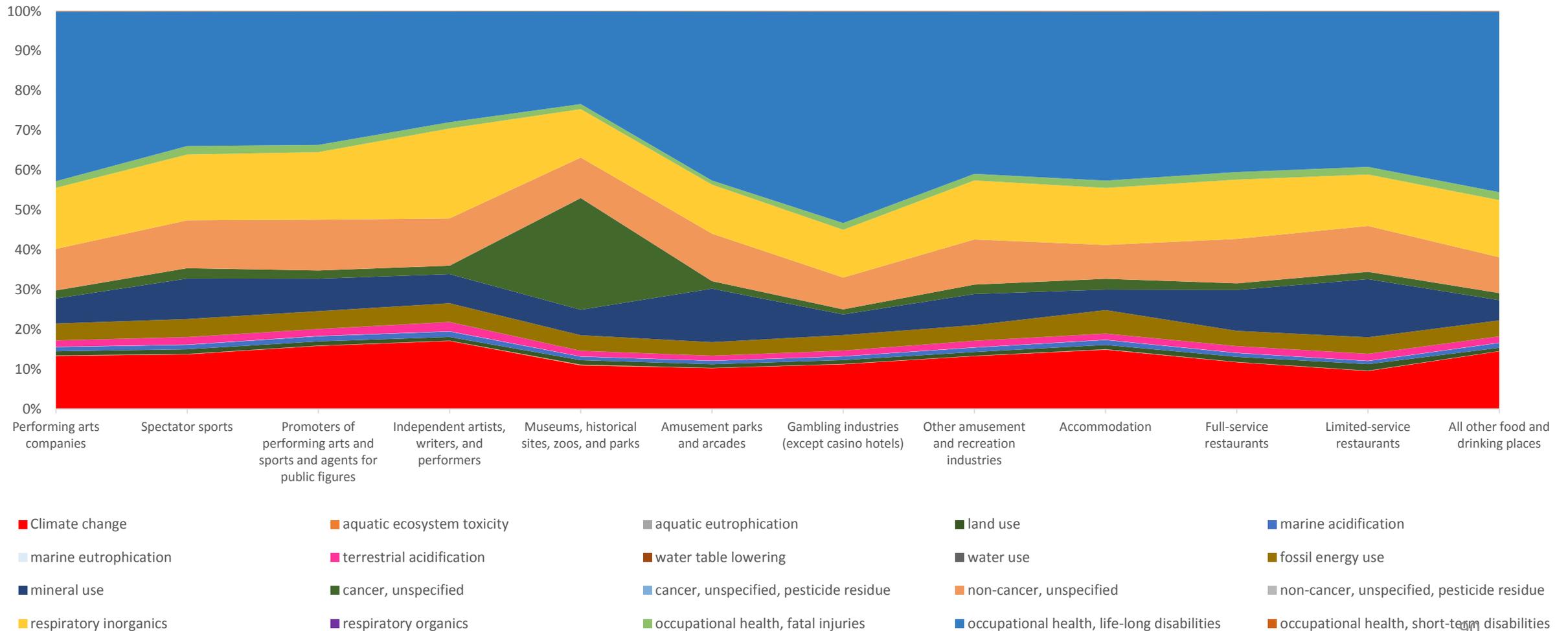
# Professional Services Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



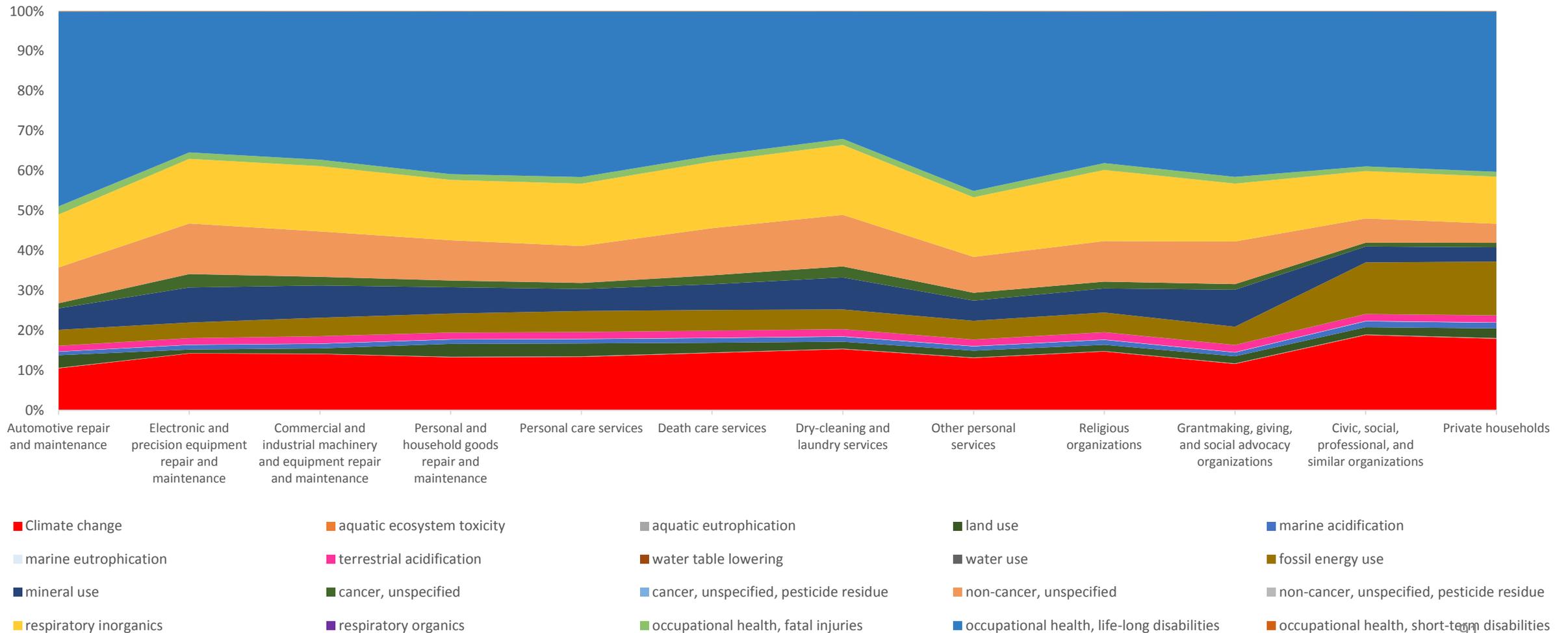
# Educational Services, Health Care, and Social Assistance Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



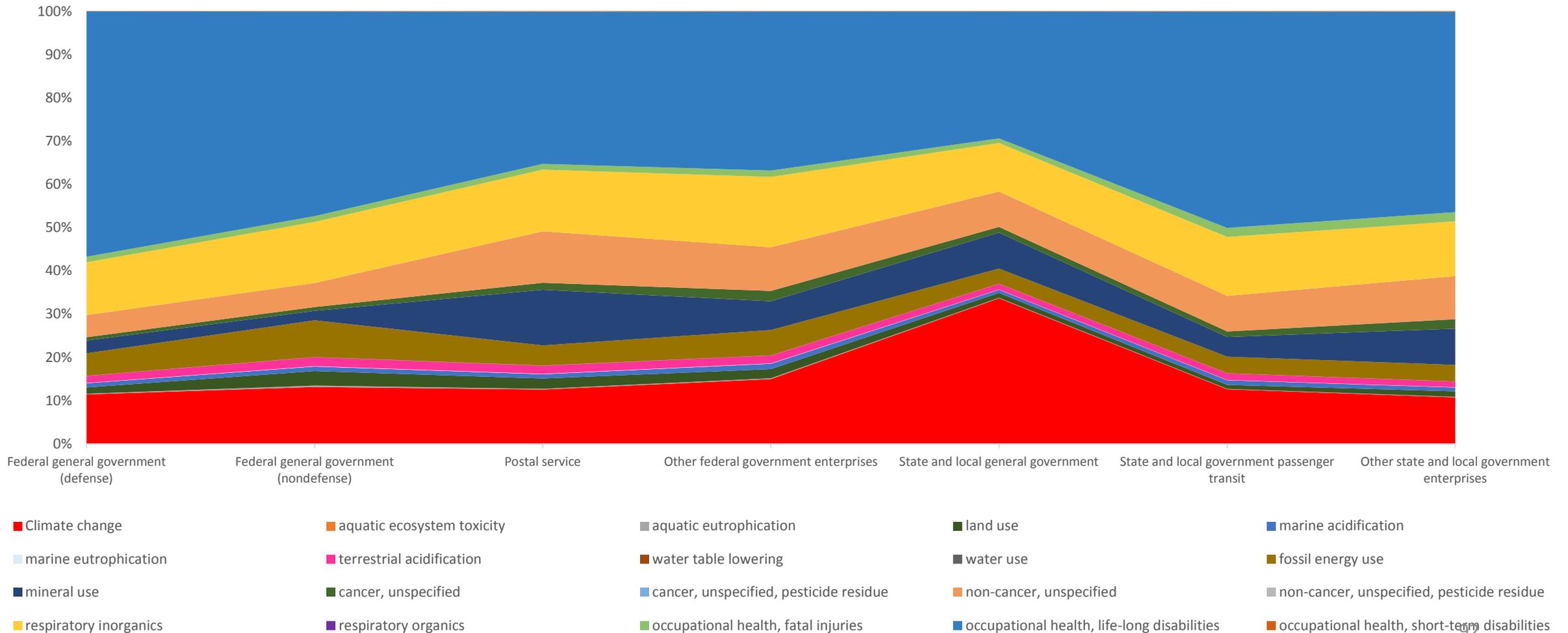
# Arts, Entertainment, Recreation, Accommodation, and Food Services Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



# All Other Non-Government Services Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



# All Government Services Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]



# Scrap, Used & Secondhand Goods, and Rest of World Adjustment Impact Valuation Results [Total Impacts (USD 2014) per USD2007 of spend]

