

USEEIO v2.0

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Disclaimer

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USEEIO Models

A family of environmentally-extended input-output (EEIO) models of the US

- Depict environmental and economic performance of all commodities and industries in the US
- Track ~2000 unique releases or resource types
- Report 20 environmental, resource and socio-economic impact indicator scores
- Built on >9 million data points
- Include formal data quality characterization of results
- [Open source data and modeling framework](#)
- Most recent version (v2.0)
- Overview article in Journal of Cleaner Production (Yang et al., 2017)

v2.0 Basic Specs

- 2012 IO data, ~2012-2017 physical flows
- 411 commodities
- 2668 flows
- 23 indicators
- Total US Consumption, Production and Household Consumption vectors (2012)

v2 New Features

- more sectors than BEA
- domestic vs. foreign input and result distinction
- price adjustment matrices
- validation proofs

v2 Improved Data Description & More Data Distribution

- National Totals by Sector by NAICS-6 datasets in lieu of separate satellite tables
- harmonization with Federal LCA Commons Elementary Flow List
- additional data provision
 - Make and Use tables
 - industry and commodity output
 - USEEIO<->BEA<->NAICS crosswalk
 - domestic versions of matrices
 - more metadata

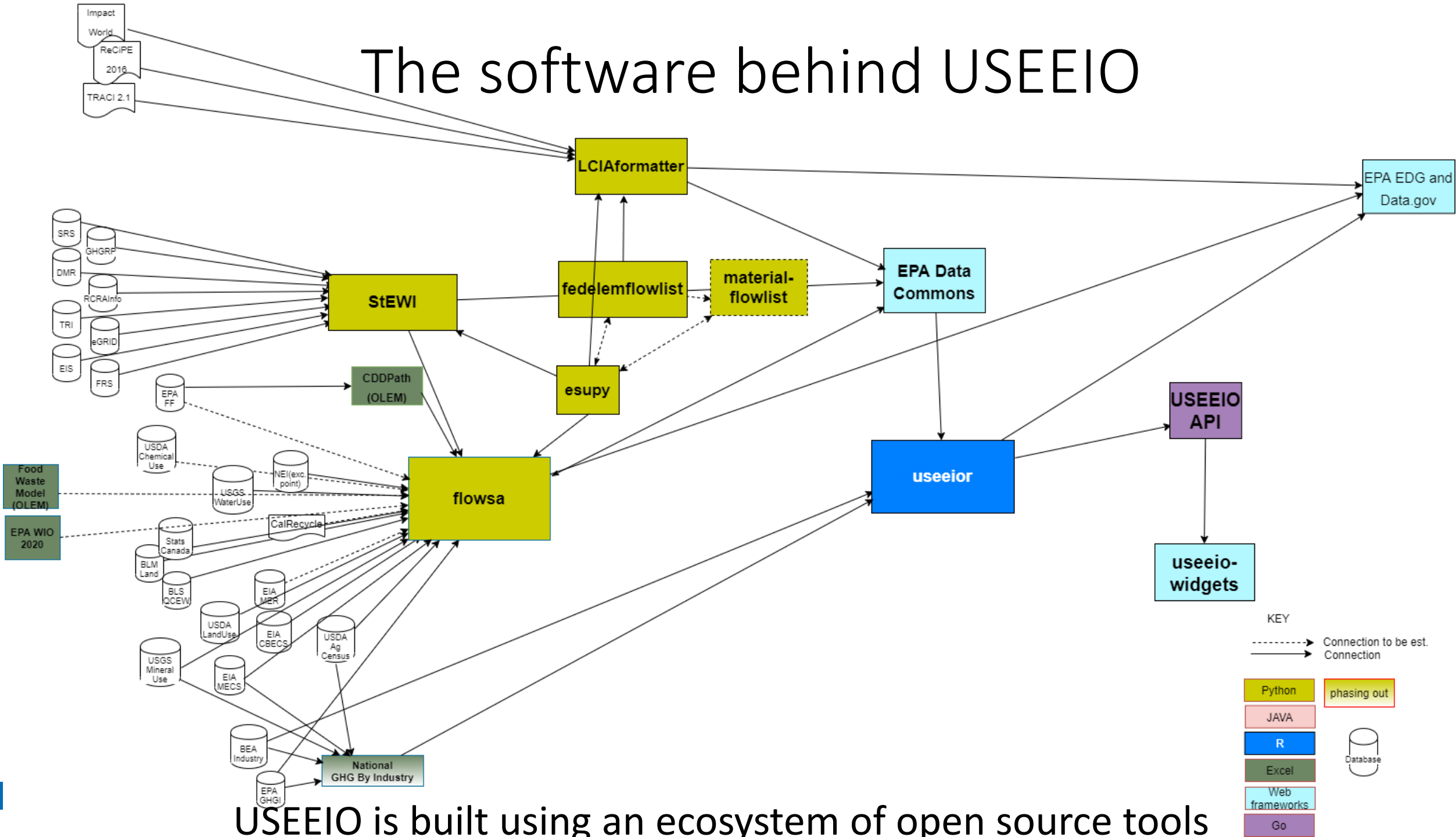
v2 Minor Changes from v1

- scrap included as a commodity (BEA, 2009)
- IO data year used as base model USD year (2012)
- U matrix renamed to N

v2.0 availability

1. [USEEIO v2.0.1-411 matrices and metadata in Excel](#)
2. openLCA JSON format [Federal LCA Commons](#)
3. [Build model in R](#) with `useeior::buildModel("USEEIOv2.0.1-411")`

The software behind USEEIO



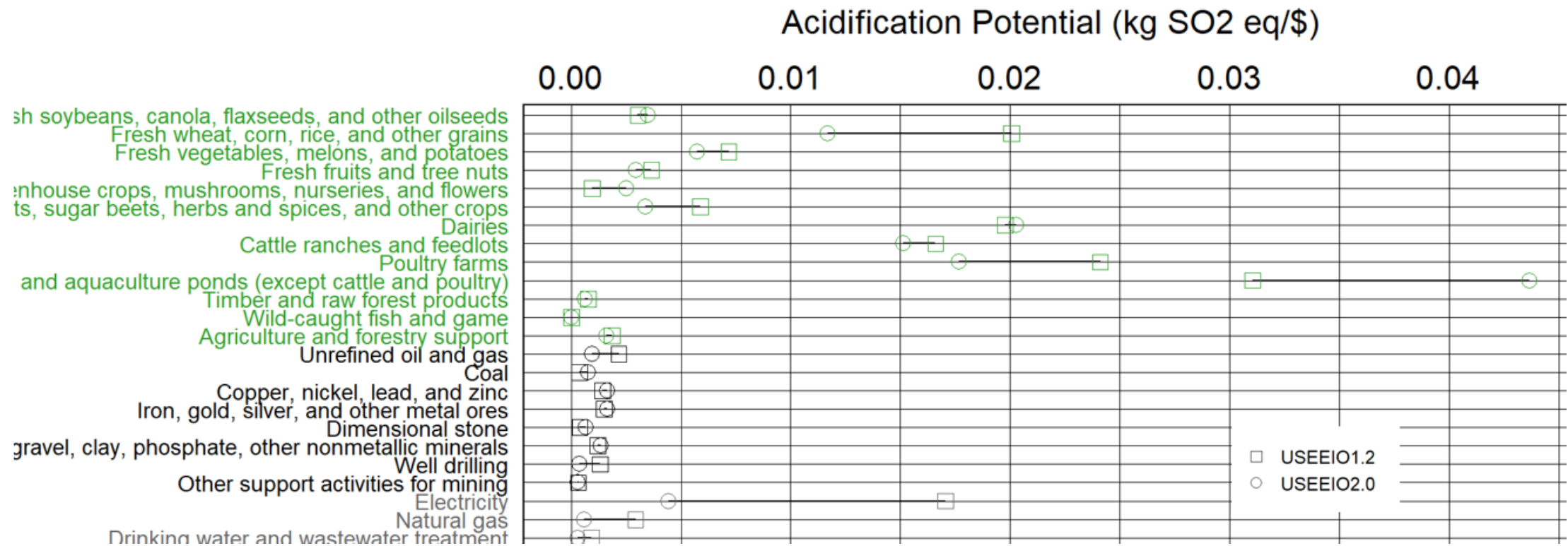
Principle Tools for National Model

1. [useeior](#) - Model specification, import of econ data, assembly, calculation
2. [flowsa](#) - Environmental/employment data preparation
3. [LCIAformatter](#) - Indicator data preparation

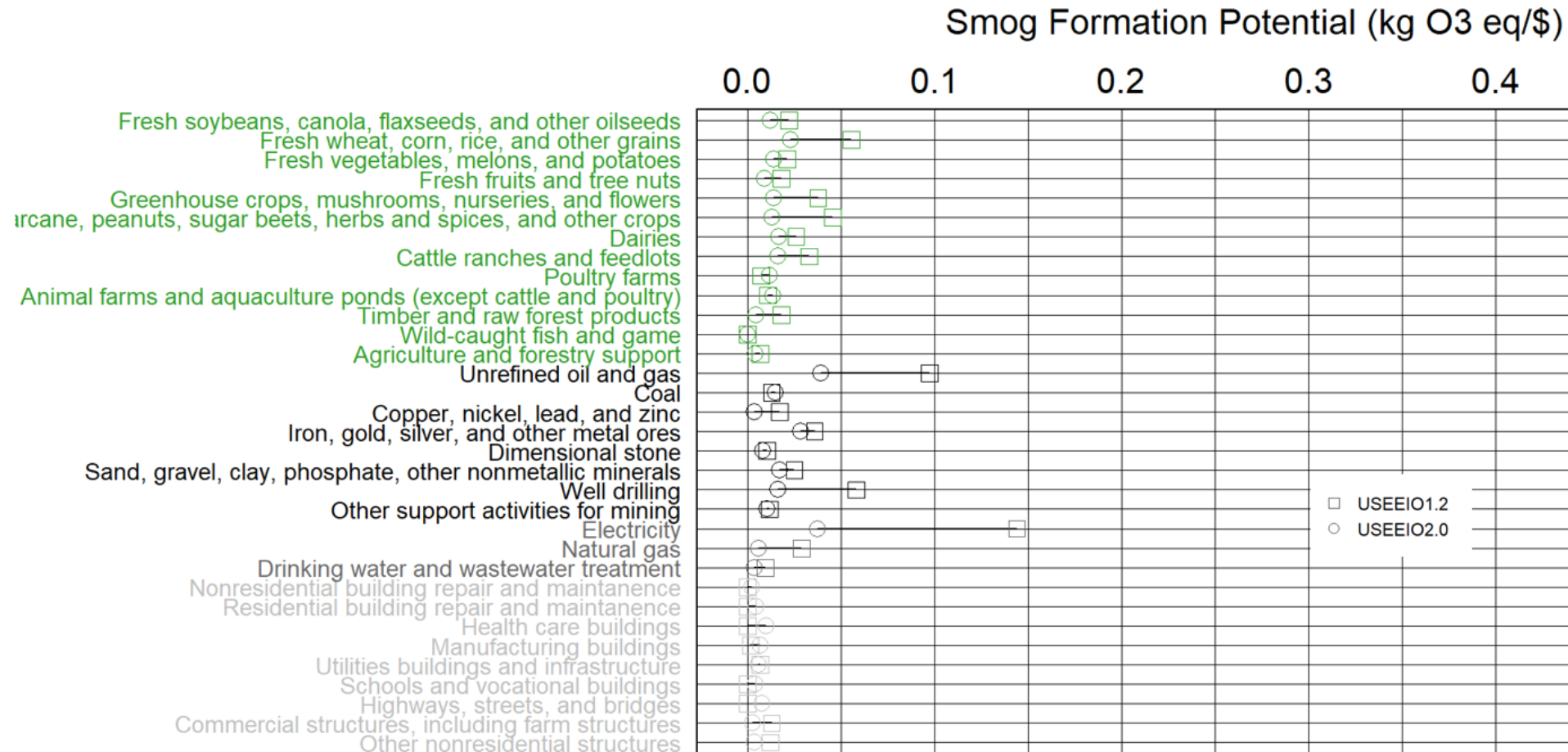
Comparing USEEIOv2 with USEEIOv1.2

1. **D**irect impact intensity coefficients (D coefficients)
2. Direct + **iN**direct intensity coefficients (N coefficients)
3. Commodity ranking based on total impacts of consumption

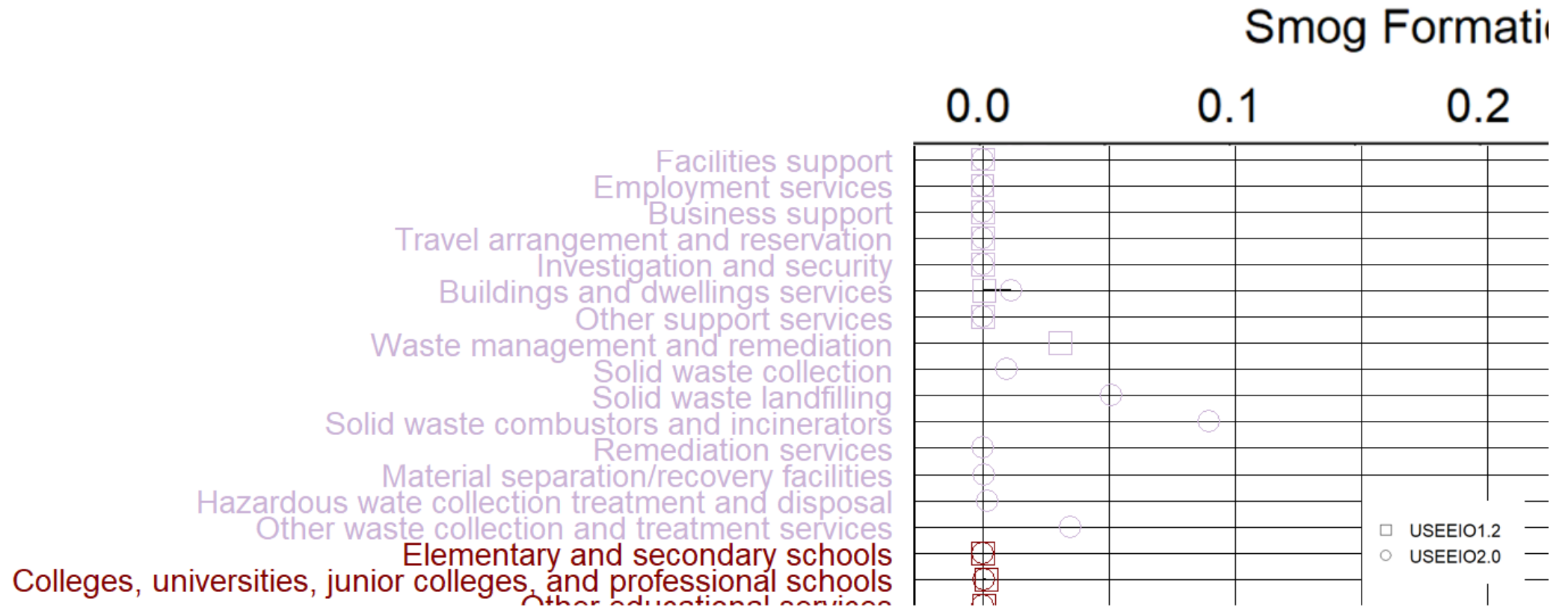
Comparing D coefficients



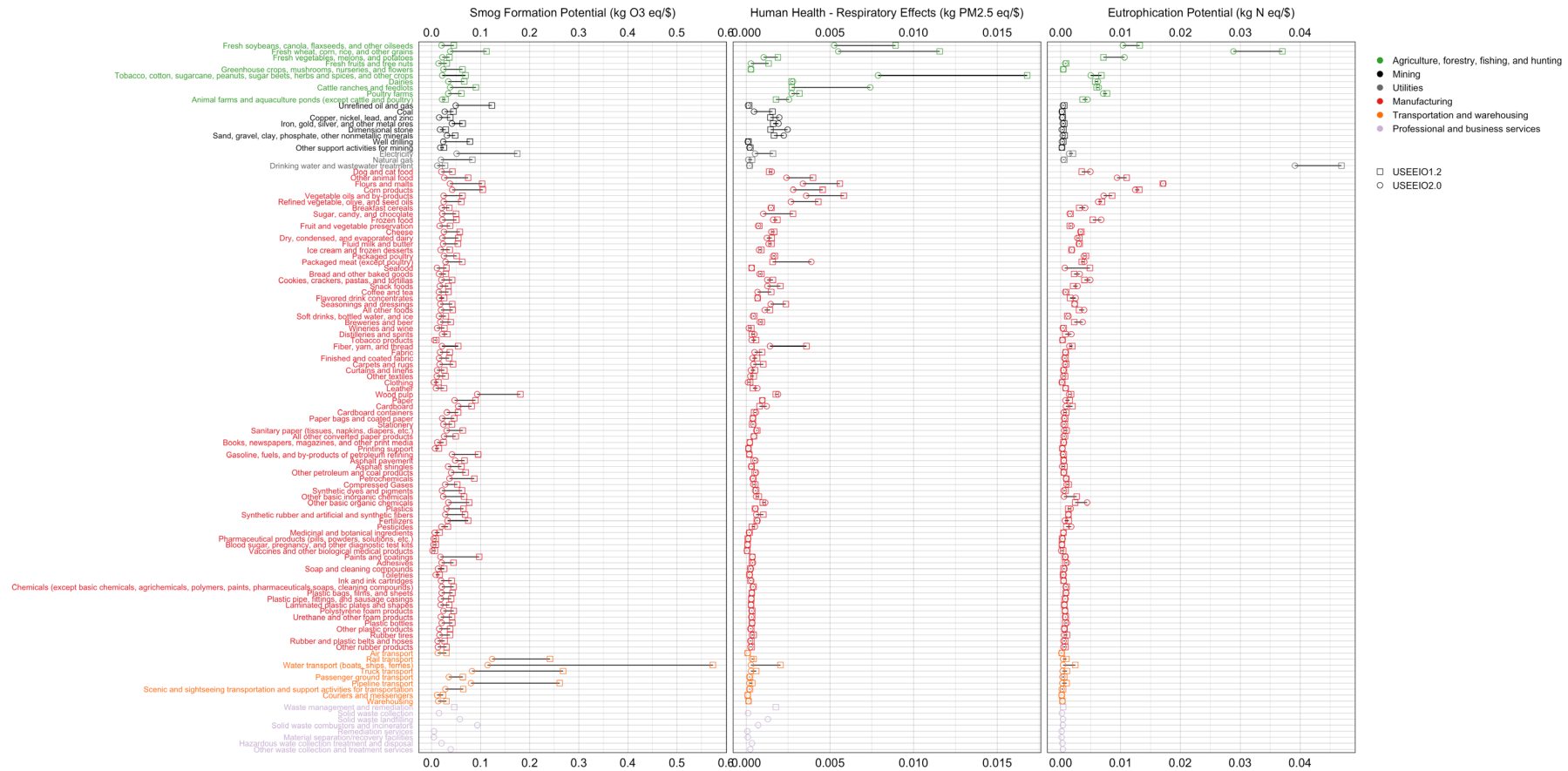
Comparing D coefficients (2)



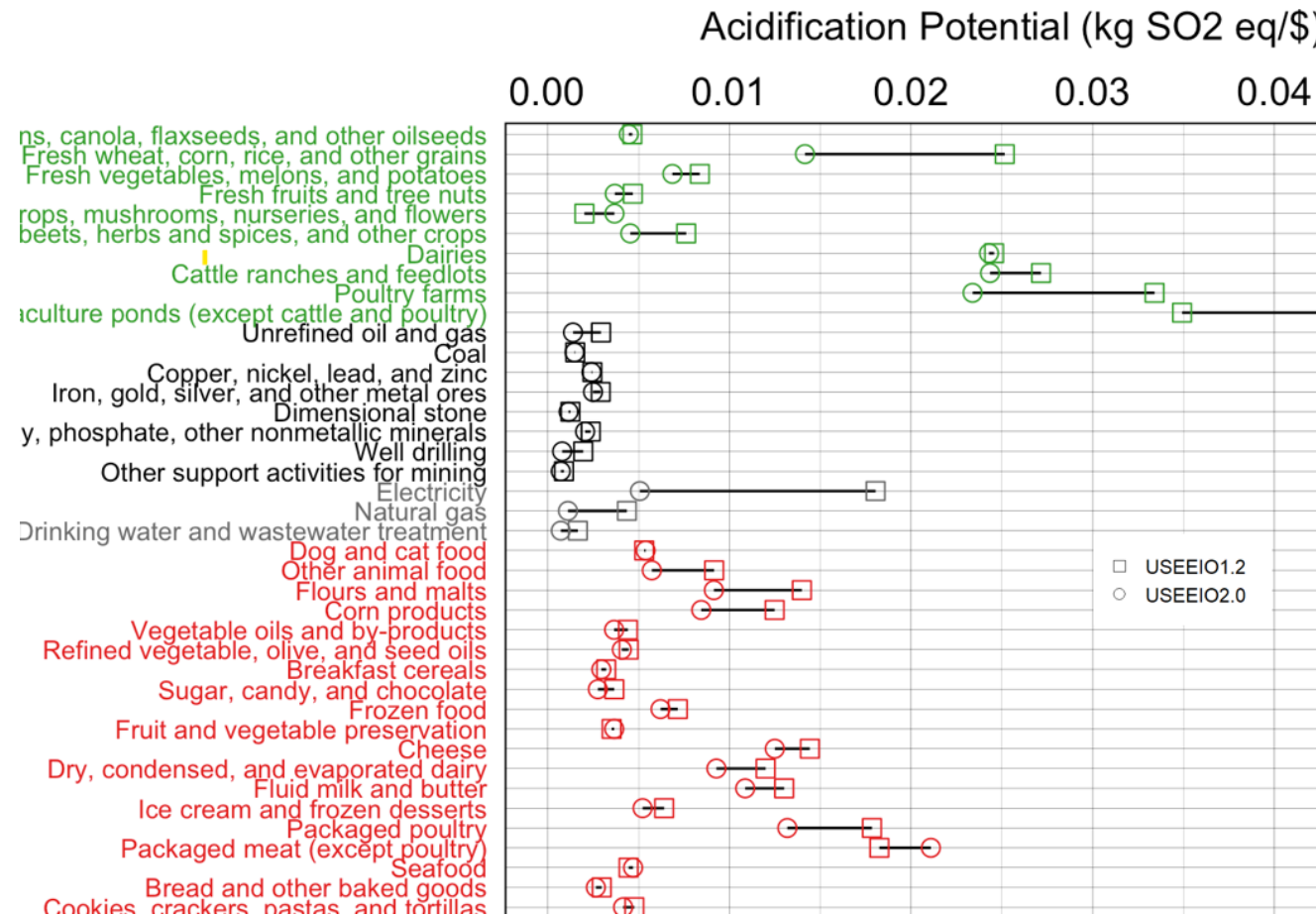
Comparing D coefficients (3)



Comparing N coefficients



Comparing N coefficients (2)



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Future Work

Near-term

- New technology introduction
- USEEIO State v1 Models
- Electricity disaggregation
- Model hybridization with process-data

Medium-term

- Import GHG coefficients for USEEIO
- WARM-USEEIO
- Waste Input-Output
- Final user component matrices

Long-term

- USEEIO-Global nested model
- Food Waste LCA

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Keep Informed

- Follow updates to the models table on our [technical content page](#) and look for upcoming training opportunities
- watch us on github as we develop new models in [useeior](#)
- Email us to request to be added to the USEEIO user email list

Contact Info

General USEEIO inquiries: ceser@epa.gov, add USEEIO in the subject line

Technical Details of USEEIOv2.0

Model Equations

Refer to the [USEEIO Technical Content page](#) OR see commodity-type model construction equations in Appendix 1 - Model Equations of the [Supply Chain GHG Factors report](#) (EPA, 2020)

Economic Data Inputs

Name	Creator	Sources	DataYears
Make and Use, Detail, Before Redefinitions, Producer Price	BEA	Bureau of Economic Analysis Industry Input-Output Accounts	2012
Gross Output by Industry	BEA	Gross Output By Industry	2002-2017
Gross Output Chain Price Index	BEA	Gross Output By Industry	2002-2017
Margins	BEA	Bureau of Economic Analysis Industry Underlying Estimates	2012
Import Matrix	BEA	Bureau of Economic Analysis Industry Input-Output Accounts	2012

Updated Environmental Data Inputs

Dataset

[National Water Withdrawal Totals By Industry 2015 v1.1](#)

[National Criteria and Hazardous Air Pollutant Totals By Industry 2017 v1.1](#)

[National Point Source Releases to Ground By Industry 2017 v1.1](#)

[National Point Source Releases to Water By Industry 2017 v1.1](#)

[National Commercial Hazardous Waste Totals by Industry 2017 v1.1](#)

[National Land Occupation Totals By Industry 2012 v1.1](#)

[National Employment Totals By Industry 2017 v1.1](#)

Mapped and Reused Environmental Data Inputs

Flows	Data Year	Ref
Mineral extraction	2014	v1.1 satellite tables
Energy extraction	2014	v1.1 satellite tables
Nitrogen and Phosphorus Releases from Agriculture	2010-2014	v1.1 satellite tables
Pesticide Releases from Agriculture	2010-2014	v1.1 satellite tables
Commercial non-hazardous waste	2014	commercial waste by industry totals
Construction non-hazardous waste	2014	commercial waste by industry totals
Commercial hazardous waste	2015	commercial waste by industry totals
Value Added	2012	Detail Use Before Redefinitions

Indicators - Impact Potential

Name	Code	Creator	Sources
Greenhouse Gases	GHG	USEPA	TRACI 2.1
Acidification Potential	ACID	USEPA	TRACI 2.1
Eutrophication Potential	EUTR	USEPA	TRACI 2.1
Freshwater Ecotoxicity Potential	ETOX	USEPA	TRACI 2.1
Human Health - Cancer	HCAN	USEPA	TRACI 2.1
Human Health - Noncancer	HNCN	USEPA	TRACI 2.1
Human Health Toxicity	HTOX	NA	Aggregation of HNCN and HCAN
Human Health - Respiratory Effects	HRSP	USEPA	TRACI 2.1
Ozone Depletion	OZON	USEPA	TRACI 2.1
Smog Formation Potential	SMOG	USEPA	TRACI 2.1

Indicators - Resource Use

Name	Code	Creator	Sources
Freshwater withdrawals	WATR	USEPA	LCIAformatter FEDEFL Inventory Methods
Land use	LAND	USEPA	LCIAformatter FEDEFL Inventory Methods
Hazardous Air Pollutants	HAPS	USEPA	LCIAformatter FEDEFL Inventory Methods
Pesticides	PEST	USEPA	LCIAformatter FEDEFL Inventory Methods
Nonrenewable Energy Use	NNRG	USEPA	LCIAformatter FEDEFL Inventory Methods
Renewable Energy Use	RNRG	USEPA	LCIAformatter FEDEFL Inventory Methods
Energy Use	ENRG	USEPA	LCIAformatter FEDEFL Inventory Methods
Minerals and Metals Use	MNRL	USEPA	LCIAformatter FEDEFL Inventory Methods

Indicators - Economic, Jobs and Waste Generation

Name	Code	Creator	Sources
Value Added	VADD	USEPA	USEEIOv1.1 - Elementary Flows and Life Cycle Impact Assessment (LCIA) Characterization Factors
Jobs Supported	JOBS	USEPA	USEEIOv1.1 - Elementary Flows and Life Cycle Impact Assessment (LCIA) Characterization Factors
Commercial RCRA Hazardous Waste	CRHW	USEPA	Analyzing economy-scale solid waste generation using the United States environmentally-extended input-output model
Commercial Municipal Solid Waste	CMSW	USEPA	Analyzing economy-scale solid waste generation using the United States environmentally-extended input-output model
Commercial Construction and Demolition Debris	CCDD	USEPA	Analyzing economy-scale solid waste generation using the United States environmentally-extended input-output model

Final Demand Vectors

Representations of final demand included in model

Vector	Formula
Production	$h_d + g_d + v_d + x + \delta$
Consumption	$h + g + v$
Household Consumption	h

h = household consumption g = government consumption i = investment d = domestic only δ = change in inventories

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Validation

Flow validation

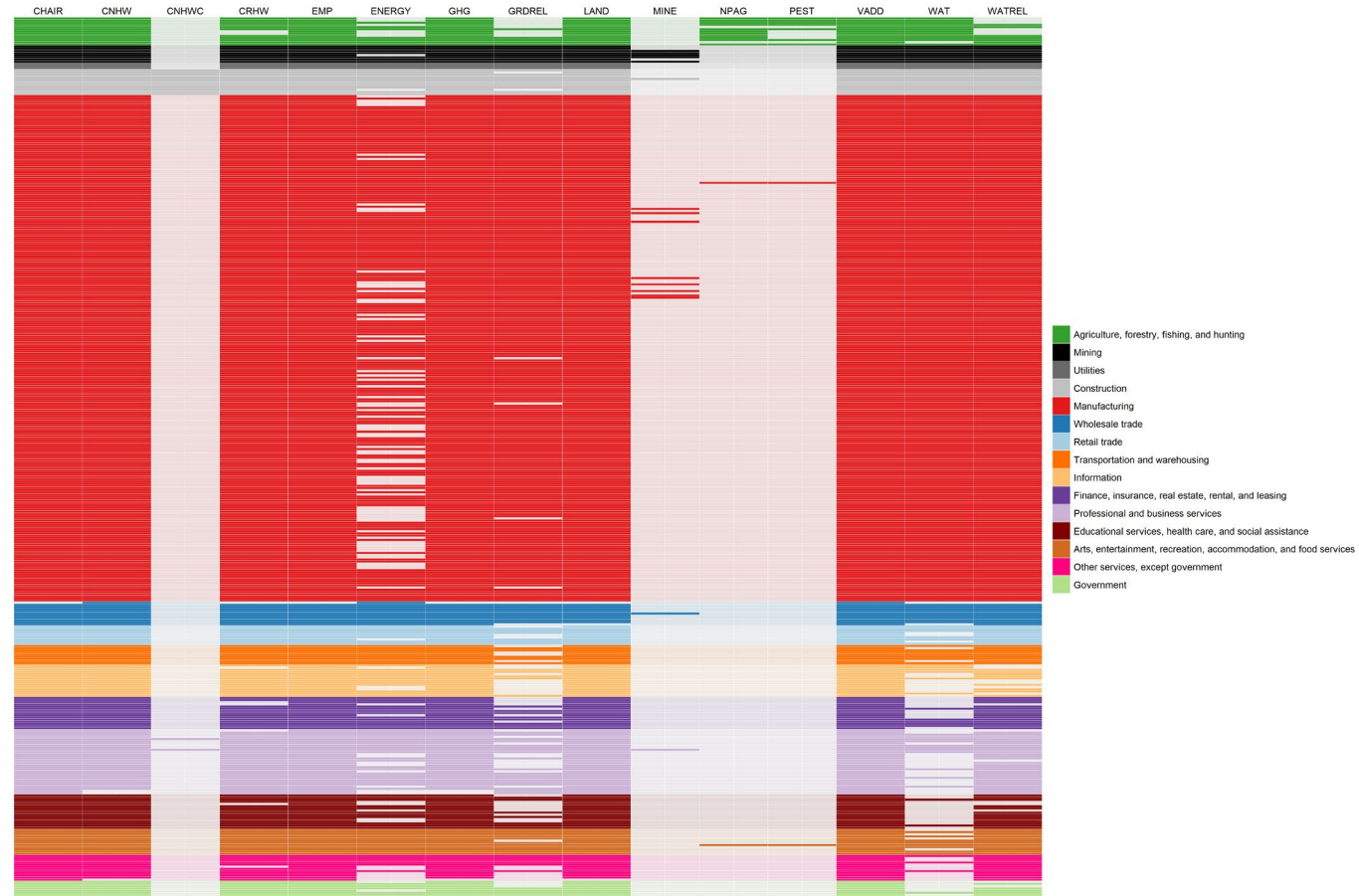
1. Source totals = national flow totals by industry
2. flow-industry mapping validation

Model validation

1. model commodity output calculation = commodity output vector
2. model total flow calculation = national flow totals by sector

[USEEIO v2.0.1-411 build and validation record](#)

Sector coverage of flows



Validating model output calc

$$q = L\hat{y}$$

q = commodity output

L = Leontief inverse of model A

y = final demand vector for US production

$\hat{}$ = diagonalized

Validating model flow calc

$$\begin{aligned}E_c &= B_{\chi,c} L \hat{y} \\E_c &= (C_m E_i')' \\C_m &= V' \hat{x}^{-1} \\B_{\chi,c} &= B_i \circ \chi V \hat{q}^{-1}\end{aligned}$$

E_c = model input flows by industry transformed into flow by commodity

$B_{\chi,c}$ = satellite matrix in commodity form, modified for χ adjustment

B_i = satellite matrix in industry form

χ = industry output ratios of environmental data year: model year

L = Leontief inverse of model A

y = final demand vector for US production

C_m = commodity mix matrix

V = Make table; q = commodity output; x = industry output

$\circ$ for Haddard product, $'$ for transpose

References

- BEA, 2009. Concepts and Methods of the U.S. Input-Output Accounts. U.S. Bureau of Economic Analysis (BEA), Washington, DC.
- Birney, Catherine, Melissa Conner, and Wesley Ingwersen. 2021. "National Water Withdrawal Totals by Industry 2015 V1.1." <https://doi.org/10.23719/1524312>.
- Birney, Catherine, Melissa Conner, Jacob Specht, and Wesley Ingwersen. 2021. "National Land Occupation Totals by Industry 2012 V1.1." <https://doi.org/10.23719/1524314>
- Birney, Catherine, Mo Li, and Wesley Ingwersen. 2021. "National Employment Totals by Industry 2017 V1.1." <https://doi.org/10.23719/1524318>.
- Bureau of Economic Analysis, 2020. Industry Underlying Estimates. <https://www.bea.gov/industry/industry-underlying-estimates> (accessed 10.29.2020).
- Bureau of Economic Analysis, 2012. Use before redefinitions producer's prices 2012 <https://www.bea.gov/industry/input-output-accounts-data> (accessed 3.11.2021).
- U.S. EPA, 2020. Supply Chain Greenhouse Gas Emission Factors for US Industries and Commodities (No. EPA/600/R-20/001). US Environmental Protection Agency, Office of Research and Development, Center for Environmental Solutions and Emergency Response. https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=CESER&dirEntryId=349324
- Ingwersen, Wesley, Li, Mo, 2021. USEEIO v2.0.1-411 Build and Validation Script. <https://doi.org/10.6084/m9.figshare.17145878.v1>
- Ingwersen, Wesley, Li, Mo, Meyer, David, 2019. Commercial Waste National Totals by NAICS and US Satellite Tables for USEEIO. <https://doi.org/10.23719/1503688>
- Ingwersen, Wesley, Li, Mo, Young, Ben, Vendries, Jorge, Birney, Catherine, 2021. USEEIO v2.0.1-411 - DATASET. <http://doi.org/10.23719/1524311>
- Li, Mo, and Ingwersen, Wesley. 2021. "Life-Cycle Impact Coefficients (N Matrix) of USEEIOv1.2 and V2.0.1-411." figshare. 2021. <https://doi.org/10.6084/m9.figshare.17269211>.
- Li, Mo, Ingwersen, Wesley, Young, B., Vendries, Jorge, Birney, Catherine, 2021. useeior v1.0.0. <https://github.com/USEPA/useeior/tree/v1.0.0>
- Meyer, D.E., Li, M., Ingwersen, W.W., 2020. Analyzing economy-scale solid waste generation using the United States environmentally-extended input-output model. Resources, Conservation and Recycling 157, 104795. <https://doi.org/10.1016/j.resconrec.2020.104795>
- U.S. EPA, 2018. 2014 National Emissions Inventory Technical Support Document. Environmental Protection Agency.
- Yang, Y., Ingwersen, W.W., Hawkins, T.R., Srocka, M., Meyer, D.E., 2017. USEEIO: A New and Transparent United States Environmentally-Extended Input-Output Model. Journal of Cleaner Production 158, 308–318. <https://doi.org/10.1016/j.jclepro.2017.04.150>
- Young, B., Birney, C., Ingwersen, W., 2021a. National Point Source Releases to Ground By Industry 2017 v1.1. <https://doi.org/10.23719/1524317>
- Young, B., Birney, C., Ingwersen, W., 2021b. National Point Source Releases to Water By Industry 2017 v1.1. <https://doi.org/10.23719/1524316>
- Young, B., Birney, C., Ingwersen, W., 2021c. National Commercial Hazardous Waste Totals by Industry 2017 v1.1. <https://doi.org/10.23719/1524319>
- Young, Ben, Catherine Birney, Caitlin Chiquelin, and Wesley Ingwersen. 2021. National Criteria and Hazardous Air Pollutant Totals by Industry 2017 v1.1. <https://doi.org/10.23719/1524315>
- Young, B., Srocka, M., Ingwersen, W., Morelli, B., Cashman, S., Henderson, A., 2021e. TRAClv2.1 for FEDEFLv1. <https://doi.org/10.23719/1522413>
- Young, B., Srocka, M., Ingwersen, W., Morelli, B., Cashman, S., Henderson, A., 2021f. FEDEFL Inventory Methods v1.0.0. <https://doi.org/10.23719/1522414>
- Young, Ben, Li, Mo, Ingwersen, Wesley, 2021. Direct impact coefficients (D matrix) of USEEIOv1.2 and v2.0.1-411 <https://doi.org/10.6084/m9.figshare.17377805>