

# An Introduction to USEEIO



Wesley Ingwersen  
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# Outline

- Theoretical background
- USEEIO overview
- Technical infrastructure
- Current work
- Planned future work
- Model resources
- Contributing

# Theoretical Basis: Input-output modeling



# Input-output modeling

- Economic modeling based on input-output tables
- Detailed (~ 400 industry) Make (industry-by-commodity) and Use (commodity-by-industry) tables released every five years based on Industry Census data
- Combined with IO techniques they can be used to estimate direct and total economic requirements
- Used to model direct and indirect economic effects

A

	S1	S2	S3	S4	S5	S6	S7
S1	.01	0.8	0.1	.04	0.3	0.1	0.8
S2	0.3	0.2	0.5	.04	0.1	0.5	0.2
S3	0.5	0.1	.01	0.1	0.5	.01	0.1
S4	0.1	0.5	0.3	0.5	.01	0.3	.01
S5	0	.01	0.3	.01	0.3	0.8	0.3
S6	0.8	0.3	0.1	0.3	0.1	0.2	.04
S7	0.2	0.5	0.1	0.1	0.1	0.1	0.1

f

	H	G
S1	109	40
S2	40	30
S3	5000	988
S4	34	100
S5	0	56
S6	100	234
S7	30	670

$$(I - A)^{-1} * f$$

W

	S1	S2	S3	S4	S5	S6	S7
Labor	.01	0.8	0.1	.04	0.3	0.1	0.8
Taxes	0.3	0.2	0.5	.04	0.1	0.5	0.2

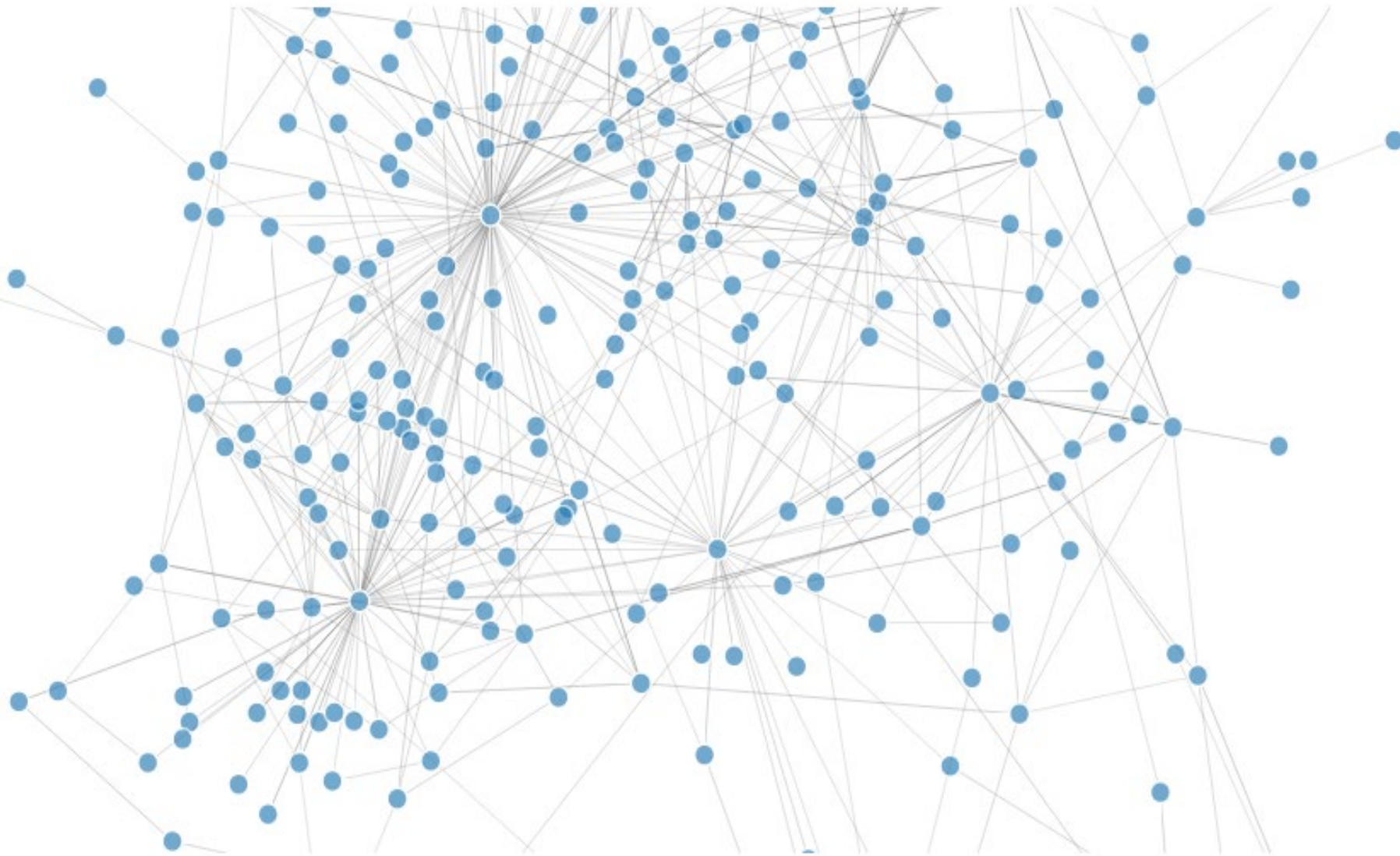
# BEA Make and Use (highly aggregated)

Use

	Commodities/Industries	11	21	22	23	31G	42	44RT	48TW	51
IOCode	Name	Agriculture, forestry, fishing, and hunting	Mining	Utilities	Construction	Manufacturing	Wholesale trade	Retail trade	Transportation and warehousing	Information
11	Agriculture, forestry, fishing, and hunting	103929	97	0	1667	252993	1376	2230	95	1
21	Mining	2629	31854	37088	12533	314942	43	63	1919	281
22	Utilities	4910	2483	2755	2912	51399	3733	10146	6161	4301
23	Construction	2899	4686	4681	175	12340	1058	2503	5550	2927
31G	Manufacturing	79825	30332	14713	308358	1929793	35287	54444	136538	108673
42	Wholesale trade	26919	5975	3886	55190	287857	35904	27093	32353	29053
44RT	Retail trade	217	179	299	90467	13441	676	7762	5272	388
48TW	Transportation and warehousing	15189	9450	19653	24126	151743	57375	75463	133966	19715
51	Information	621	561	1230	6182	24943	15071	21517	6045	243759

Make

	Industries/Commodities	11	21	22	23	31G	42	44RT	48TW	51
IOCode	Name	Agriculture, forestry, fishing, and hunting	Mining	Utilities	Construction	Manufacturing	Wholesale trade	Retail trade	Transportation and warehousing	Information
11	Agriculture, forestry, fishing, and hunting	444114 ...	...	...	932	14 ...	...	...	...	...
21	Mining	...	412649 ...	...	20714	14740	471 ...	...	...	...
22	Utilities	...	10	396067	2662 ...	...	...	30	533 ...	...
23	Construction	...	...	...	1352303 ...	...	...	...	...	...
31G	Manufacturing	...	752 ...	...	11979	5604650	49259 ...	...	...	...
42	Wholesale trade	1097 ...	...	...	5145	6786	1442009 ...	...	1369 ...	...
44RT	Retail trade	130 ...	...	...	5033	17013 ...	...	1459094	4499 ...	...
48TW	Transportation and warehousing	1 ...	...	731	1140 ...	...	107	63	1068557 ...	...
51	Information	...	...	...	1855	974	5829	2524 ...	...	126731 ...



Nodes are BEA commodities; lines are \$ inputs

# Environmentally-extended input-output modeling

- Direct environmental releases or resource use (stressors) associated with sectors can be linked to the economic input-output data, and used with indicators

C

	H2O	Cr	N2O	Land	P
Water Use	1	0	0	0	0
GHG	0	0	200	0	0
Mineral Use	0	120	0	0	0
Eutrophication	0	0	0	0	4.1

B

	S1	S2	S3	S4	S5	S6	S7
H2O	10	1	0	5	100	92	1
Cr	0.6	10	2	0.6	10	2	0.6
N2O	0.5	0.1	.01	0.1	0.5	.01	0.1
Land	0.1	2	0.6	10	2	2	0.6
Wast	0	10	2	10	1	0	5
DD	0.8	0.3	0.1	0.3	0.1	0.2	.04
P	1	2	0.6	10	2	2	0

A

	S1	S2	S3	S4	S5	S6	S7
S1	.01	0.8	0.1	.04	0.3	0.1	0.8
S2	0.3	0.2	0.5	.04	0.1	0.5	0.2
S3	0.5	0.1	.01	0.1	0.5	.01	0.1
S4	0.1	0.5	0.3	0.5	.01	0.3	.01
S5	0	.01	0.3	.01	0.3	0.8	0.3
S6	0.8	0.3	0.1	0.3	0.1	0.2	.04
S7	0.2	0.5	0.1	0.1	0.1	0.1	0.1

f

	H	G
S1	109	40
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$$C * B * (I - A)^{-1} * f$$

# Model Overview

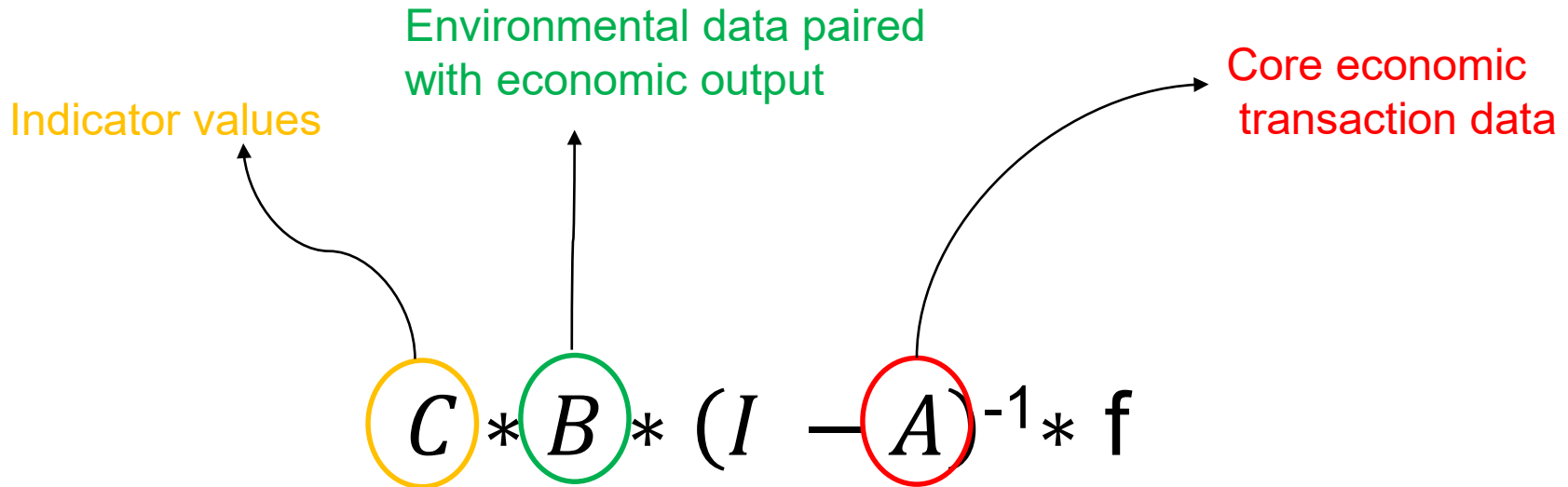


# USEEIO

- An environmentally-extended input-output model of the US
- Level of resolution: 385 goods and services
- 1875 unique releases or resource types
- 20 environmental, resource and socio-economic impact indicators
- Pulls in TRI, NEI, GHGI, DMR, RCRAINFO + USGS/USDA/EIA data, other public sources
  - > 9 million data points processed
- Formal data quality characterization
- Open source data and modeling framework
- v1.1 is the most current model release



# Basic model formula



A = commodity x commodity direct requirements matrix (made from IO table)  
B = Satellite tables, elementary flow x commodity matrix  
C = characterization factor x elementary flow LCIA matrix  
f = commodity final demand vector



## USEEIO – Economic Underpinning (A)

- Use Bureau Economic Analysis 2007 detailed make and use data before redefinitions
- Perform scrap adjustment
- Commodity x commodity direct requirements matrix and industry-technology assumption<sup>1</sup>

<sup>1</sup> Suh et al. 2010. Generalized Make and Use Framework for Allocation in LCA Journal of Industrial Ecology

# Environmental Satellite Tables (B)

- Satellite tables begin with publicly-available data from government sources

<b>EPA</b>	<ul style="list-style-type: none"><li>• National Emissions Inventory: CAPs and HAPs</li><li>• Toxics Release Inventory: Toxic substances</li><li>• Greenhouse Gas (GHG) Reporting Program: GHGs</li><li>• Discharge Monitoring Report: Nutrients and toxic substances</li></ul>
<b>US Department of Agriculture</b>	<ul style="list-style-type: none"><li>• Agricultural Chemical Use Program: Pesticides and nutrients</li><li>• Census of Agriculture: Land occupation</li><li>• Farm and Ranch Irrigation Survey: Water withdrawal and release</li></ul>
<b>US Geological Survey</b>	<ul style="list-style-type: none"><li>• Minerals Commodity Survey: Mineral use</li></ul>
<b>Energy Information Administration</b>	<ul style="list-style-type: none"><li>• Monthly Energy Review: Energy use</li></ul>
<b>Other</b>	<ul style="list-style-type: none"><li>• Major Uses of Land in the United States (Nickerson et al., 2011): Land occupation</li><li>• Water Use in the United States (Maupin et al., 2014): Water release and withdrawal</li></ul>

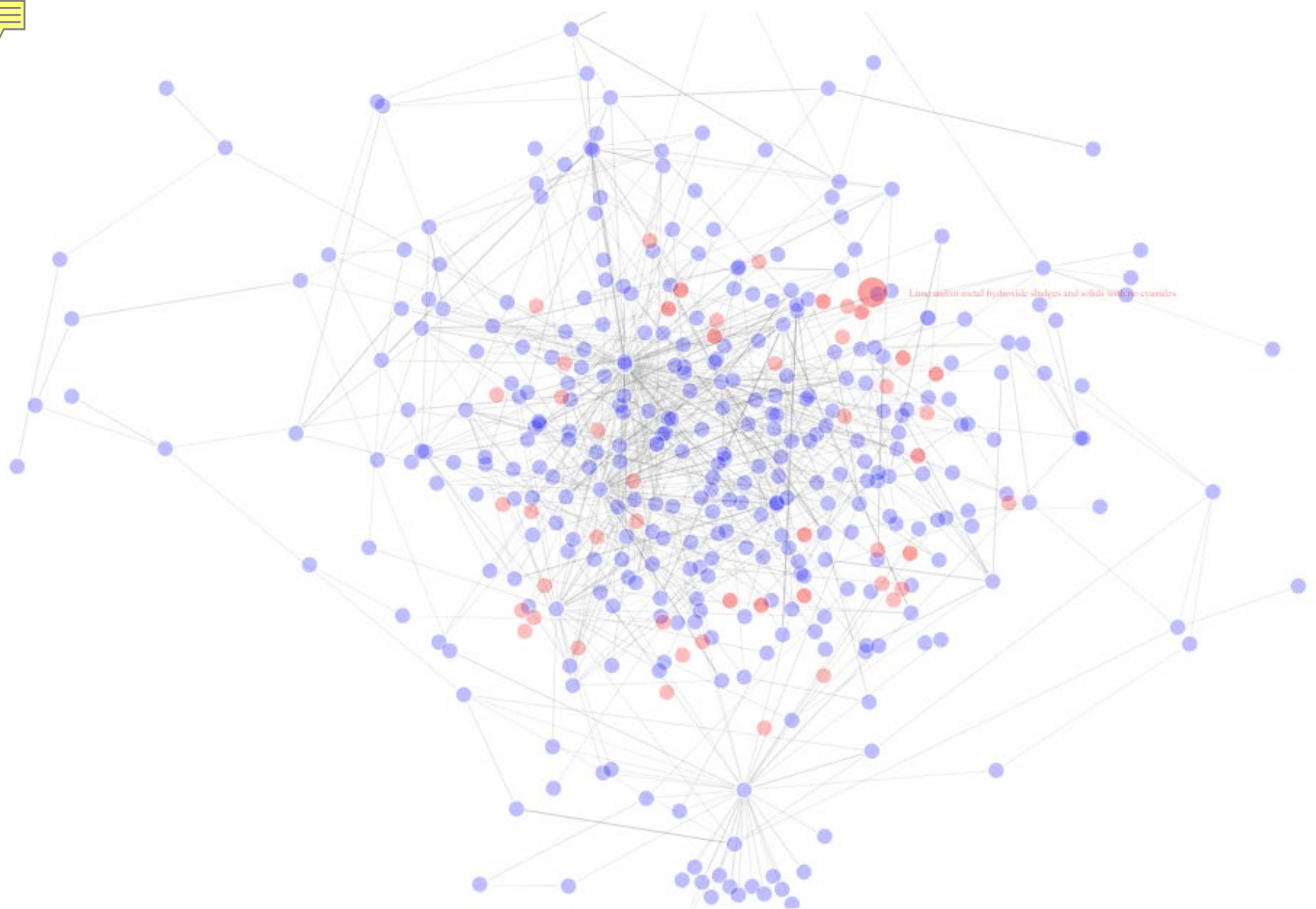
# Example satellite table

A B C D E F G H I J K L M N O P Q R S T

## Exchanges

Elementary Flow Information					Activity Information			Flow Quantity		Uncertainty Information					Data Quality				
Name	CAS Number (if applicable)	Category	Subcategory	UUID	Name	Code	Location	Amount	Unit (per \$ output)	Distribution	Expected value	Dispersion	Minimum	Maximum	Flow Reliability	Temporal correlation	Geographic correlation	Flow	Technologic
GLYPHOSATE POT. SALT	70901121, 33	water	unspecified		Oilseed farming	1111A0	US	6.16E-05	kg	Triangul	6.2E-05		2.79E-06	0.00011	3	1	1	1	1
Atrazine	1912249	water	unspecified		Grain farming	1111B0	US	8.55E-06	kg	Triangul	8.6E-06		1.3E-06	1.38E-05	3	1	1	1	1
Glyphosate-isopropylammonium	38641940	water	unspecified		Oilseed farming	1111A0	US	2.78E-05	kg	Triangul	2.8E-05		8.77E-07	5.06E-05	3	1	1	1	1
Acetochlor	34256821	water	unspecified		Grain farming	1111B0	US	6.07E-06	kg	Triangul	6.1E-06		8.72E-07	9.98E-06	3	1	1	1	1
Metam-sodium	137428	water	unspecified		Vegetable and mel	111200	US	2.24E-05	kg	Triangul	2.2E-05		4.12E-08	9.03E-05	3	1	1	1	1
Glyphosate-isopropylammonium	38641940	water	unspecified		Grain farming	1111B0	US	1.9E-05	kg	Triangul	1.9E-05		3.34E-07	3.59E-05	3	1	1	1	1
Metolachlor	51218452	water	unspecified		Grain farming	1111B0	US	4.64E-06	kg	Triangul	4.6E-06		2.03E-07	8.15E-06	3	1	1	1	1
GLYPHOSATE POT. SALT	70901121, 33	water	unspecified		Grain farming	1111B0	US	1.47E-05	kg	Triangul	1.5E-05		3.47E-07	2.74E-05	3	1	1	1	1
Sulfuric acid	7664939	water	unspecified		Vegetable and mel	111200	US	2.26E-06	kg	Triangul	2.3E-06		2.13E-08	1.18E-05	3	1	1	1	1
MINERAL OIL	8006619	water	unspecified		Fruit and tree nut f	111300	US	0	kg	Triangul	0		0	0	4	1	1	1	1
Sulfur	7704349	water	unspecified		Fruit and tree nut f	111300	US	3.63E-07	kg	Triangul	3.6E-07		0	1.86E-06	3	1	1	1	1
DICHLOROPROPENE	542756, 100	water	unspecified		Vegetable and mel	111200	US	1.25E-06	kg	Triangul	1.3E-06		1.22E-09	1.06E-05	3	1	1	1	1
Sulfur	7704349	water	unspecified		Vegetable and mel	111200	US	1.27E-07	kg	Triangul	1.3E-07		0	3.42E-07	3	1	1	1	1
Glyphosate-isopropylammonium	38641940	water	unspecified		Other crop farming	111900	US	5.77E-06	kg	Triangul	5.8E-06		8.17E-19	1.68E-05	3	1	1	1	1
Glyphosate	1071836	water	unspecified		Grain farming	1111B0	US	4.09E-06	kg	Triangul	4.1E-06		9.78E-08	7.65E-06	3	1	1	1	1
Atrazine	1912249	water	unspecified		Grain farming	1111B0	US	4.6E-07	kg	Triangul	4.6E-07		2.43E-07	7.03E-07	3	1	1	1	1
Glyphosate	1071836	water	unspecified		Oilseed farming	1111A0	US	4.34E-06	kg	Triangul	4.3E-06		1.94E-07	7.55E-06	3	1	1	1	1
METHYLCARBAMODITHIOIC A	137417	water	unspecified		Vegetable and mel	111200	US	8.5E-07	kg	Triangul	8.5E-07		8.94E-09	3.94E-06	3	1	1	1	1
Ethephon	16672870	water	unspecified		Other crop farming	111900	US	4.51E-07	kg	Triangul	4.5E-07		0	1.04E-06	3	1	1	1	1
GLYPHOSATE POT. SALT	70901121, 33	water	unspecified		Grain farming	1111B0	US	1.75E-06	kg	Triangul	1.7E-06		1.9E-07	3.88E-06	3	1	1	1	1
MINERAL OIL	8006619	water	unspecified		Fruit and tree nut f	111300	US	0	kg	Triangul	0		0	0	4	1	1	1	1
Metolachlor	51218452	water	unspecified		Oilseed farming	1111A0	US	1.28E-06	kg	Triangul	1.3E-06		2.38E-07	1.92E-06	3	1	1	1	1
Glyphosate-isopropylammonium	38641940	water	unspecified		Grain farming	1111B0	US	1.79E-06	kg	Triangul	1.8E-06		5.38E-08	3.3E-06	3	1	1	1	1
Glyphosate-isopropylammonium	38641940	water	unspecified		Grain farming	1111B0	US	1.63E-06	kg	Triangul	1.6E-06		1.06E-07	3.64E-06	3	1	1	1	1
Propanil	709388	water	unspecified		Grain farming	1111B0	US	3.72E-07	kg	Triangul	3.7E-07		0	2.89E-06	3	1	1	1	1
2,4-D, 2-ETHYLHEXYL ESTER	1928434	water	unspecified		Oilseed farming	1111A0	US	5.82E-06	kg	Triangul	5.8E-06		3.9E-07	1.07E-05	3	1	1	1	1
Metolachlor	51218452	water	unspecified		Grain farming	1111B0	US	2.07E-07	kg	Triangul	2.1E-07		1.89E-08	3.39E-07	3	1	1	1	1

Contents General Information Exchanges Compiled Main SW Compiled Main Air Sources



## USEEIO Indicators (C)

- **Potential Environmental Impacts** – acidification, respiratory effects of criteria pollutants, carcinogenic and non-carcinogenic toxicity effects, climate change, eutrophication, freshwater ecotox, smog formation, ozone depletion
- **Resource Use** – water, land, minerals
- **Environmental Releases** - HAPs, metals, pesticides
- **Economic & Social indicators** – value added, jobs
- **Waste Generated** – Hazardous waste\*, MSW\*, Food\*, C&D\*

## Final Demand (f)

- Model results are scaled by final end-consumer (governments or household) demand for goods and services
- Demand is in the form of Production and Consumption
  - $\text{Consumption} = \text{Household} + \text{Government} + \text{Investment}$
  - $\text{Production} = \text{Consumption} + \text{Exports} - \text{Imports}$

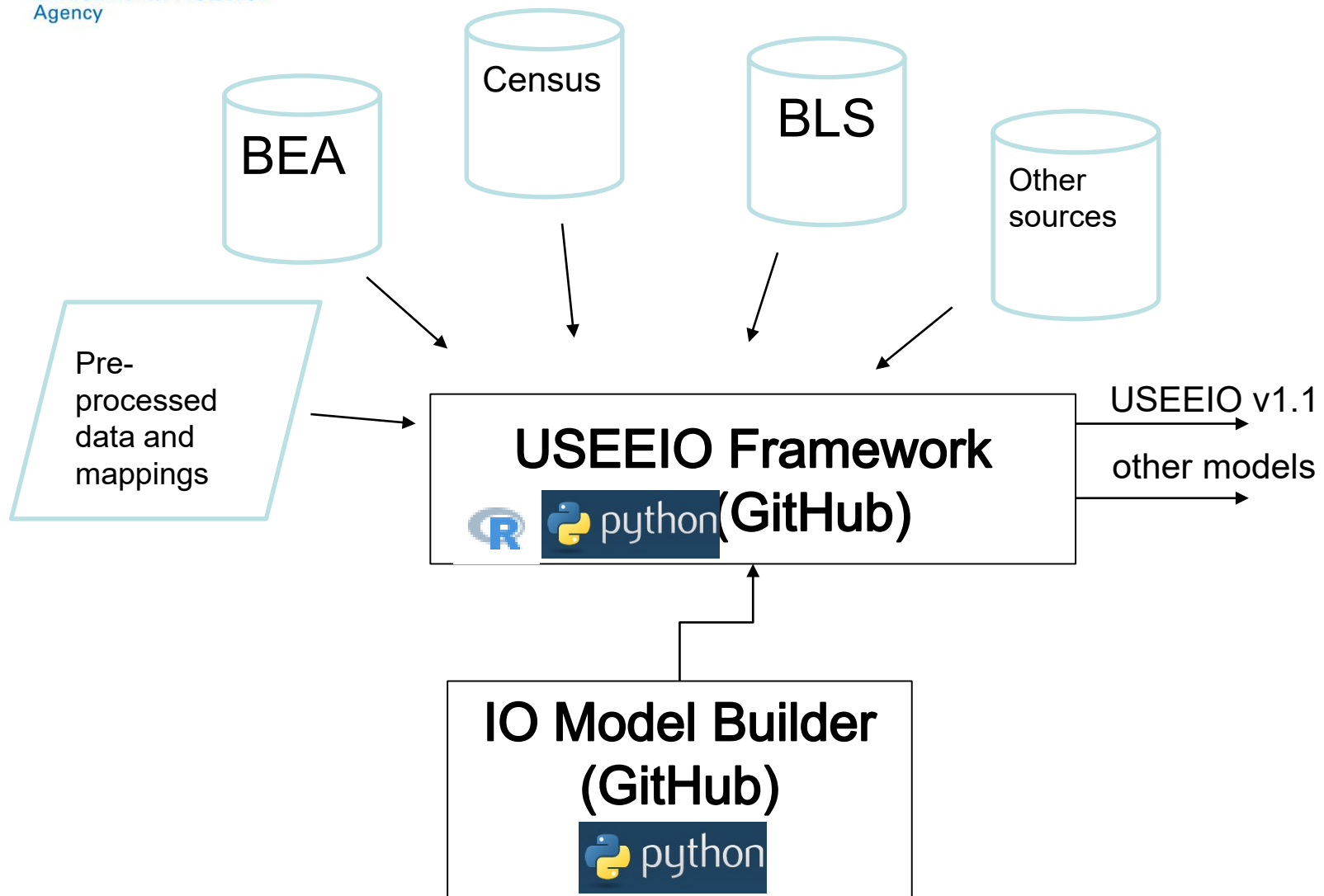


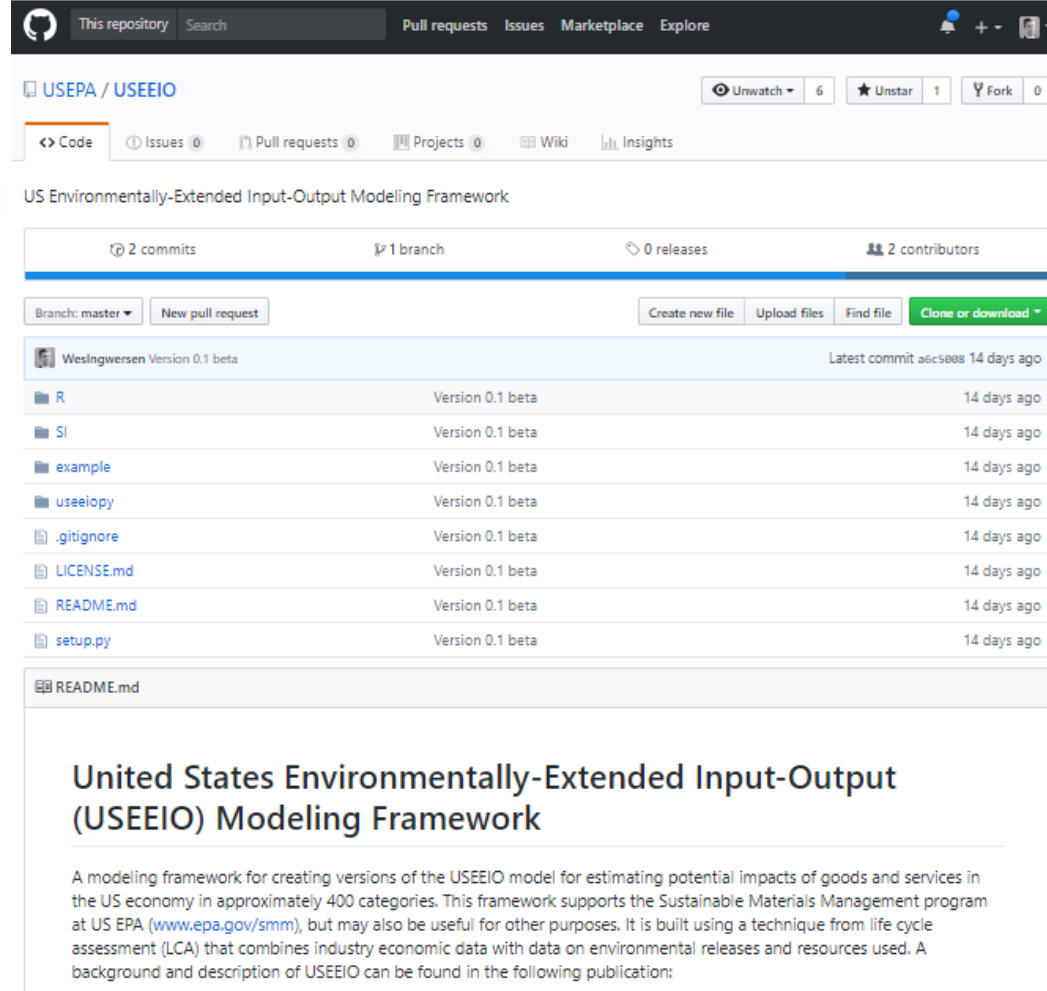
## Level of Detail and Data Quality

- Built with > 10 million data points
- Consulted curators/stewards of datasets on best uses
- Avoided double counting in case of overlap
- Applying USEPA LCA Data Quality Assessment guidelines to score data quality at the flow level for the datasets

Data Quality				
Flow Reliability	Flow Representativeness			
	Temporal correlation	Geographical correlation	Technological correlation	Data collection methods
3	1	2	1	5

# USEEIO: Technical Infrastructure





The screenshot shows the GitHub repository for USEPA / USEEIO. The repository is titled "US Environmentally-Extended Input-Output Modeling Framework". It has 2 commits, 1 branch, 0 releases, and 2 contributors. The repository is currently on the master branch. The file list shows the following files: R, SI, example, useeio.py, .gitignore, LICENSE.md, README.md, and setup.py. All files were last committed 14 days ago. The README.md file is selected, showing the title "United States Environmentally-Extended Input-Output (USEEIO) Modeling Framework" and a description of the framework.

USEPA / USEEIO

Unwatch 6 Unstar 1 Fork 0

Code Issues 0 Pull requests 0 Projects 0 Wiki Insights

US Environmentally-Extended Input-Output Modeling Framework

2 commits 1 branch 0 releases 2 contributors

Branch: master New pull request Create new file Upload files Find file Clone or download

Weslingwersen Version 0.1 beta Latest commit a6c5ee8 14 days ago

File	Version	Commit
R	Version 0.1 beta	14 days ago
SI	Version 0.1 beta	14 days ago
example	Version 0.1 beta	14 days ago
useeio.py	Version 0.1 beta	14 days ago
.gitignore	Version 0.1 beta	14 days ago
LICENSE.md	Version 0.1 beta	14 days ago
README.md	Version 0.1 beta	14 days ago
setup.py	Version 0.1 beta	14 days ago

README.md

## United States Environmentally-Extended Input-Output (USEEIO) Modeling Framework

A modeling framework for creating versions of the USEEIO model for estimating potential impacts of goods and services in the US economy in approximately 400 categories. This framework supports the Sustainable Materials Management program at US EPA ([www.epa.gov/smm](https://www.epa.gov/smm)), but may also be useful for other purposes. It is built using a technique from life cycle assessment (LCA) that combines industry economic data with data on environmental releases and resources used. A background and description of USEEIO can be found in the following publication:

- Open source framework (R and Python)  
<https://www.github.com/usepa/useeio>
- Supports model transparency, and model variations developed and maintained by others

## Current Work (FY19)

- MSW, CDD, and Haz waste satellite tables + indicators
- Food subsystem final demand
- Detailed state models in 2-region form (state, RoUS)
- Major USEEIO framework update to increase flexibility, simplicity
- Incorporate 2012 detailed IO tables
- Update year of EPA-based satellite tables

## Planned Future Work

- Framework for scenario analysis
- More explicit material and waste tracking
- Link with a global MRIO model
- Improved waste modeling



# Model Resources

## [Documentation](#)

Environmental Extensions (v1.1)

- [Satellite tables](#)
- [Indicators and their factors](#)

[Model components and results in matrix format](#) (v1.1)

[Full model in openLCA format](#)

[Model code base](#)

## USEEIO Current and Former Team Members

- Wesley Ingwersen (EPA, Technical Lead/Programmer/Modeler)
- David Meyer (EPA, Modeler)
- Mo Li (CSRA, Programmer/Modeler)
- Michael Srocka (GreenDelta, API developer)
- Yi Yang (CSRA)
- Troy Hawkins (ERG)



## Disclaimer

The U.S. Environmental Protection Agency through its Office of Research and Development collaborated in the research described here. It has not been subject to Agency review and does not necessarily reflect the views of the Agency. No official endorsement should be inferred