

Development of *Water Withdrawal Vector* for Economic Input-Output Life Cycle Assessment

LCA IX

Oct 1, 2009

Mike Blackhurst

Chris Hendrickson

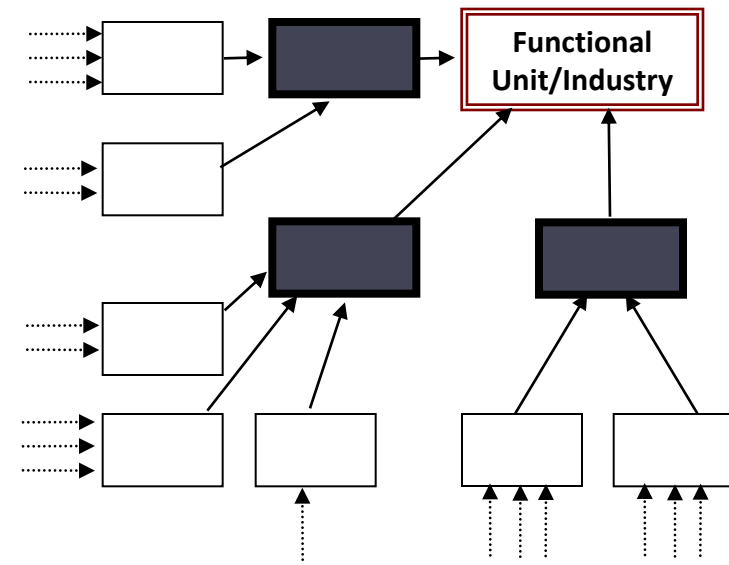
Jordi Sels i Vidal

Carnegie Mellon University

Economic Input-Output LCA

- Uses economic interdependencies to track upstream impacts
- Couples economic input-output models with impact “vector” for impact assessment
- Helps address boundary and circularity in LCAs

$$\text{Impact} = \text{Vector} \times [I - A]^{-1} \times \text{Final Economic Demand}$$



EIO-LCA Impact Vectors

- Vector = $\frac{\text{Direct impact}}{\text{Direct economic output}}$ for each economic sector
- Examples of economic sectors
 - Grain Farming
 - Painting and Coating Manufacturing
- Example Impacts
 - Greenhouse gases (mass / \$)
 - Energy use (energy / \$)
- Study goal: Prepare a water withdrawal vector (water use/\$) for 2002 benchmark model

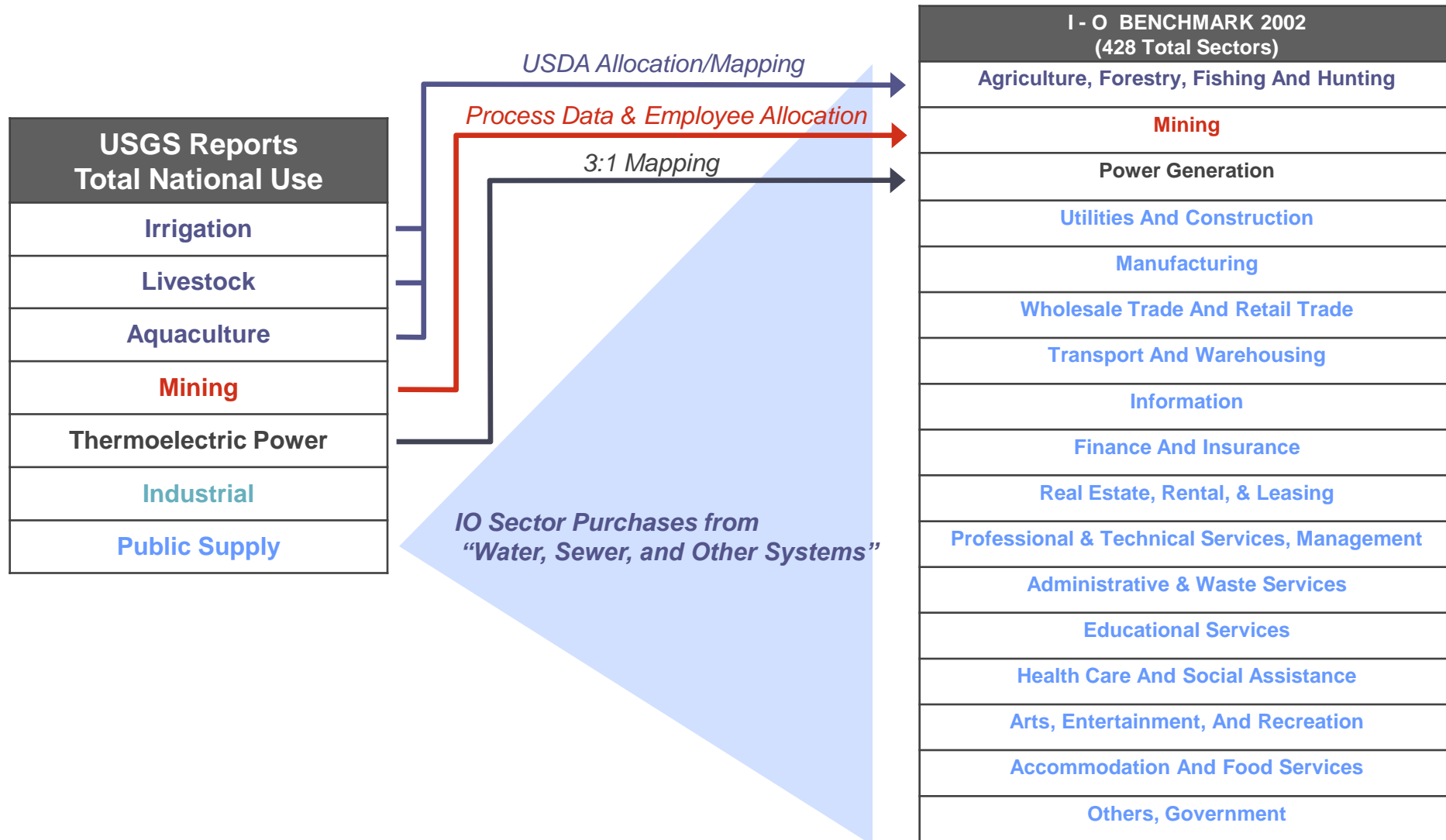
History of Water Use in EIO-LCA

- 1982 US Census surveyed water use
- 1982 data in 1992 benchmark EIO-LCA model
 - Withdrawal (“Intake”)
 - Reused
 - Discharged Untreated
 - Discharged Treated
- *2002 effort documents “withdrawal” only*

Acronyms

- USDA = United State Department of Agriculture
- USGS = United State Geological Survey
- BEA = Bureau of Economic Analysis
- BLS = Bureau of Labor Statistics

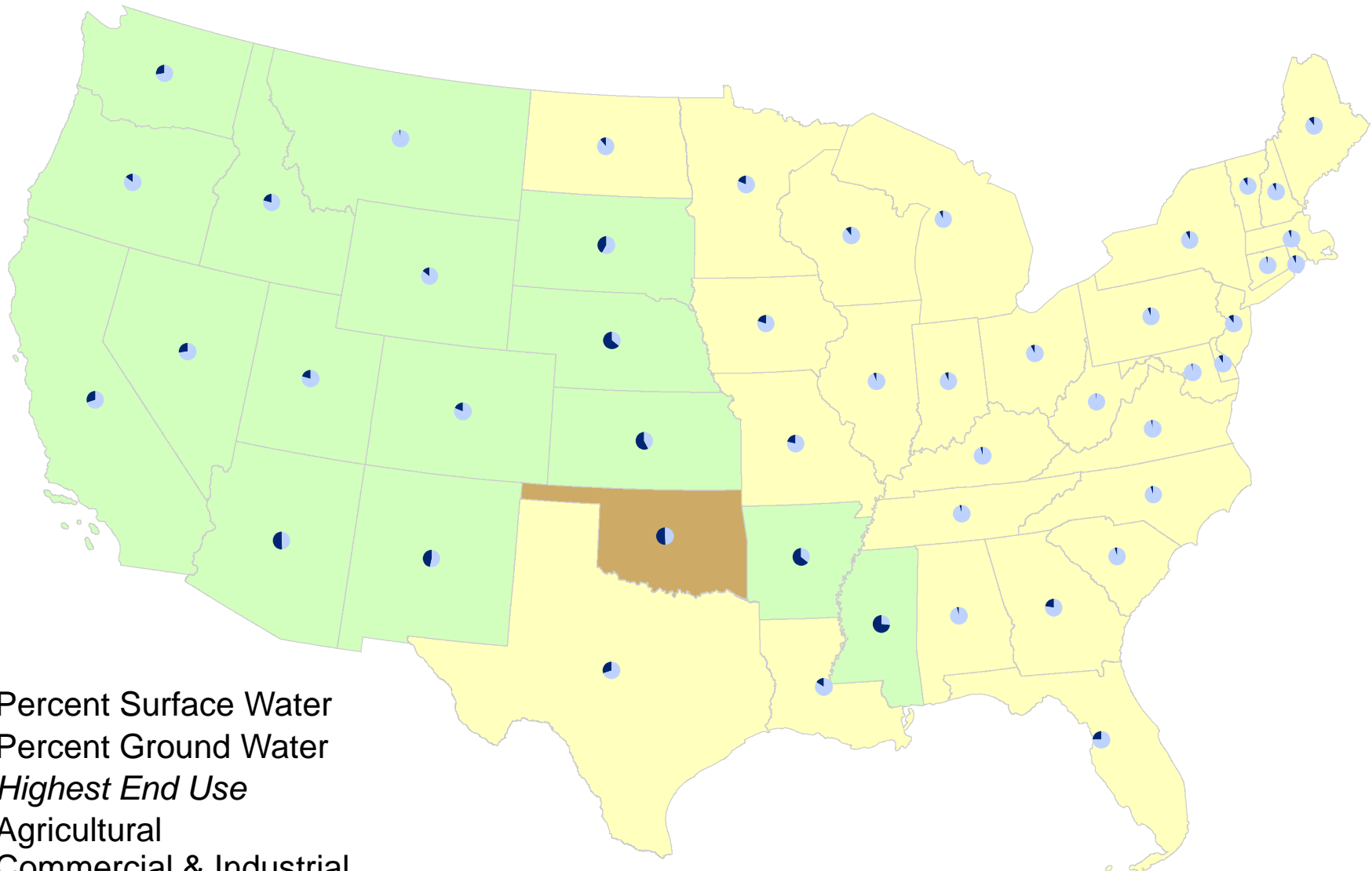
Vector Preparation Method



USGS Water Withdrawal Data

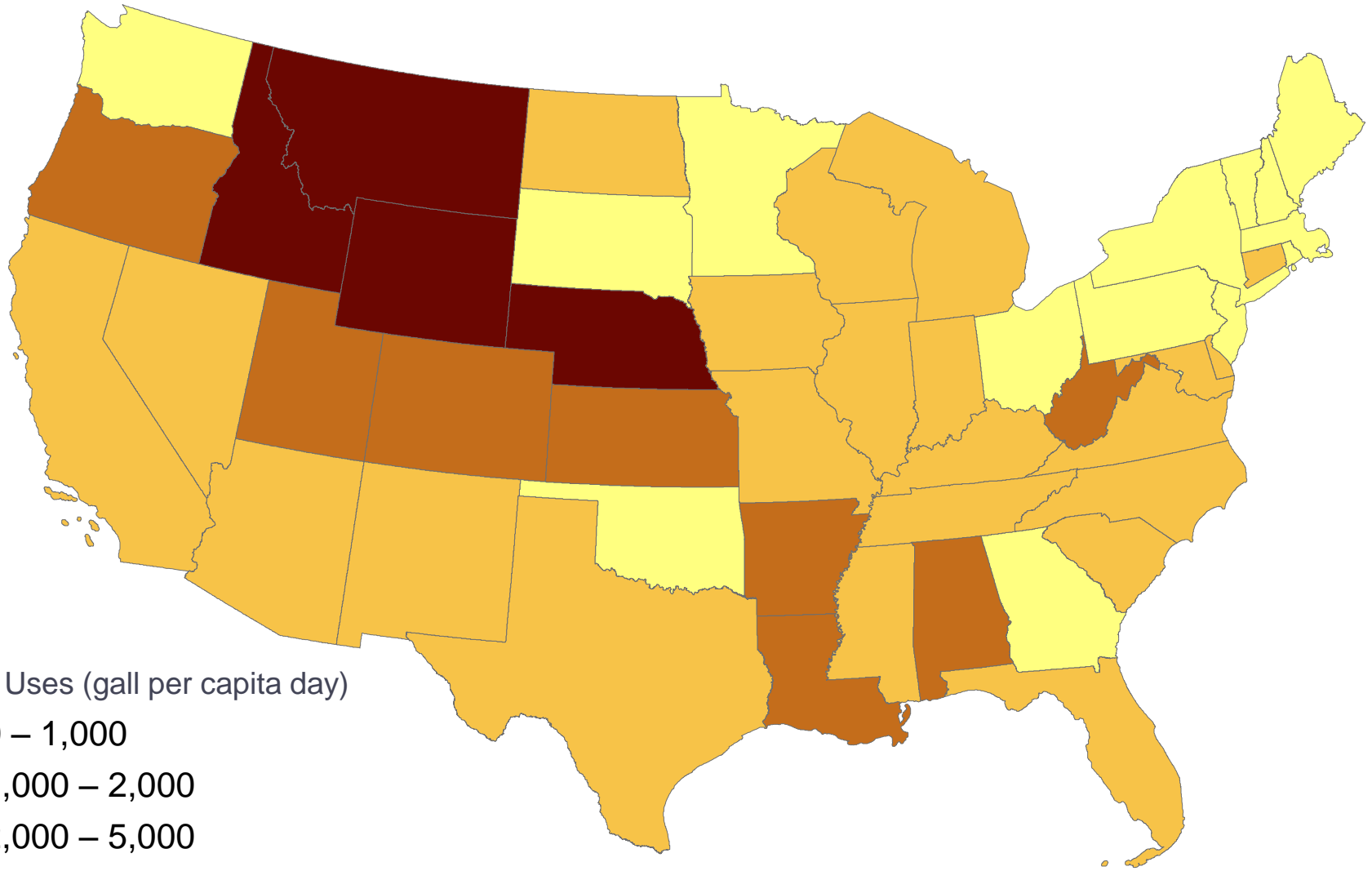
- “Estimated Use Of Water In The United States”
 - Published every 5 years (xxx0, xxx05)
 - State level data
 - 8 sector resolution
- Relies mainly on states to report use
- No quality assurance/quality control mentioned

USGS Water Supply & End Use



- Percent Surface Water
- Percent Ground Water
- State Highest End Use**
- Agricultural
- Commercial & Industrial
- Thermoelectric

USGS Per Capita Demands



All End Uses (gall per capita day)

- 0 – 1,000
- 1,000 – 2,000
- 2,000 – 5,000
- 5,000 – 15,000

Summary of Allocation Data

End Use	Allocation Method	Allocation Data Reference(s)	Year of Allocation Data	Data Collection Method
Power Generation	3-1 mapping	BEA, Industry Use of Commodities	2002	Post processed survey data collected from the Economic Censuses
Irrigation	USDA yields & irrigation rates	USDA, Census of Agriculture USDA, Irrigation Census	2002-2003	Survey data
Non-Domestic Public Supply*	Purchases from <i>Water, sewage, & other</i>	BEA, Industry Use of Commodities	2002	Post processed survey data collected from the Economic Censuses
Industrial	By employee as reported by Canada	Statistics Canada, Industrial Water Use Industry Canada, Canadian Industry Statistics US BLS, Economic Census Other Misc Process LCA Estimates	2005	Survey data
Livestock & Aquaculture	USDA yields & irrigation rates	USDA, Census of Agriculture USDA, Irrigation Census	2002-2003	Survey data
Mining	By employee as reported by Canada	Professional literature Government reports	2002-2008	Experiments, estimates, survey data

Allocation Results

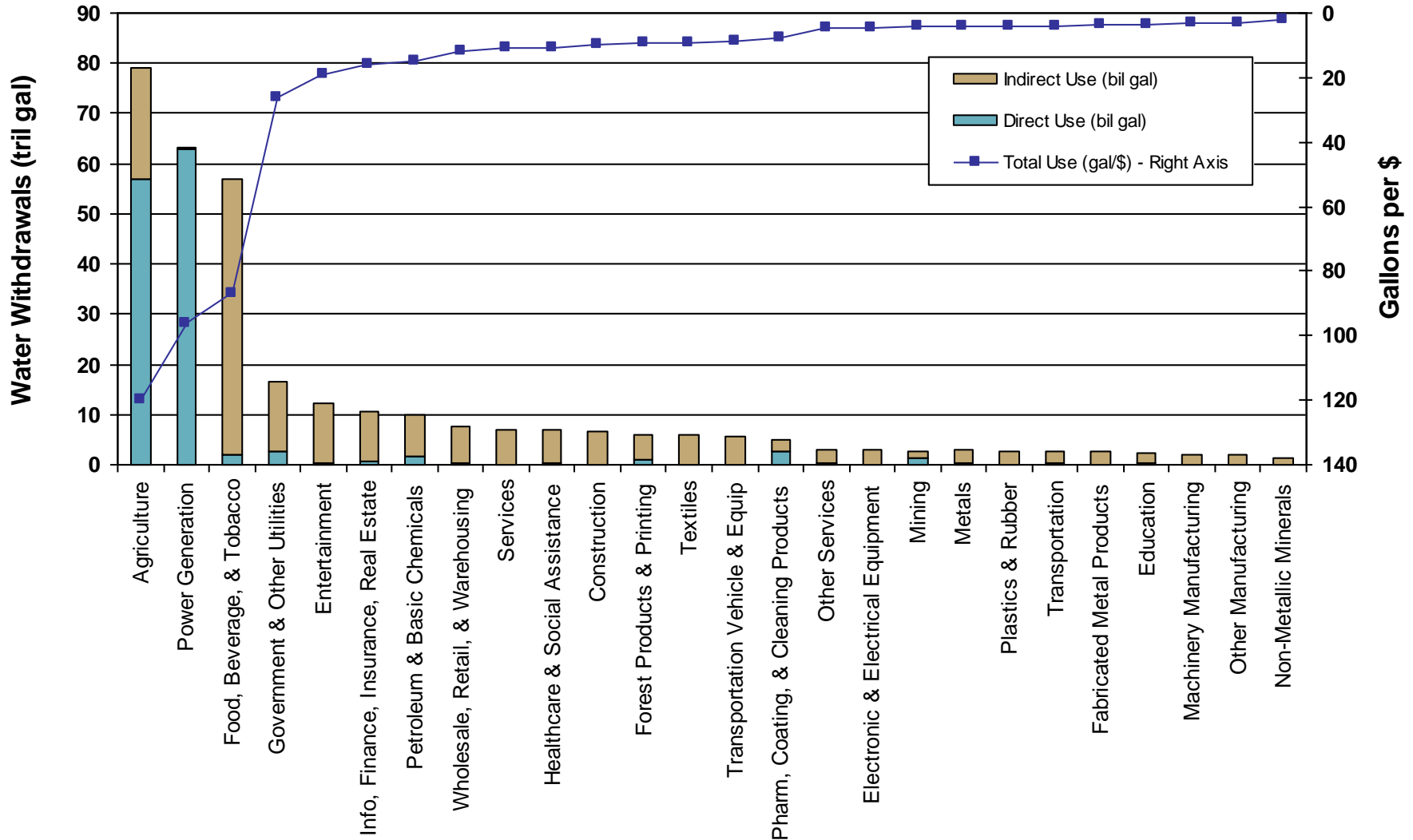
USGS Sector	USGS Direct Use Estimate (bil gal in 2000)	Water Use (%)	Allocation Method	Allocated Total (bil gal)	Scaling Factor To Match USGS Total
Power Generation	71,000	48%	3-1 mapping	71,000	1
Irrigation	50,000	34%	USDA yields & irrigation rates	27,000	1.8
Non-Domestic Public Supply*	6,500	5%	Purchases from <i>Water, sewage, & other</i>	7,600	1.1
Industrial	7,200	5%	By employee as reported by Canada	66,300	9.2
Livestock & Aquaculture	2,040	1%	USDA yields & irrigation rates	2,700	0.24
Mining	1,300	1%	By employee as reported by Canada	974	0.76
Total	140,440	93.5% (*)			

*Self and publicly supplied household use not represented in vector.

Example IO-LCA Results - \$1M of *Grain Farming*

Grain Farming	Water Withdrawal (mil gal)
<i>Direct Water Use</i>	1,300
<i>Indirect Uses</i>	
Power generation and supply	8
Pesticide and other agricultural chemical manufacturing	1.6
Cotton farming	1.0
Fertilizer Manufacturing	0.7
All other crop farming	0.6
Fruit farming	0.4
Cattle ranching and farming	0.34
Sugarcane and sugar beet farming	0.26
Stone mining and quarrying	0.26
Other basic organic chemical manufacturing	0.12
Vegetable and melon farming	0.12
Etc.	

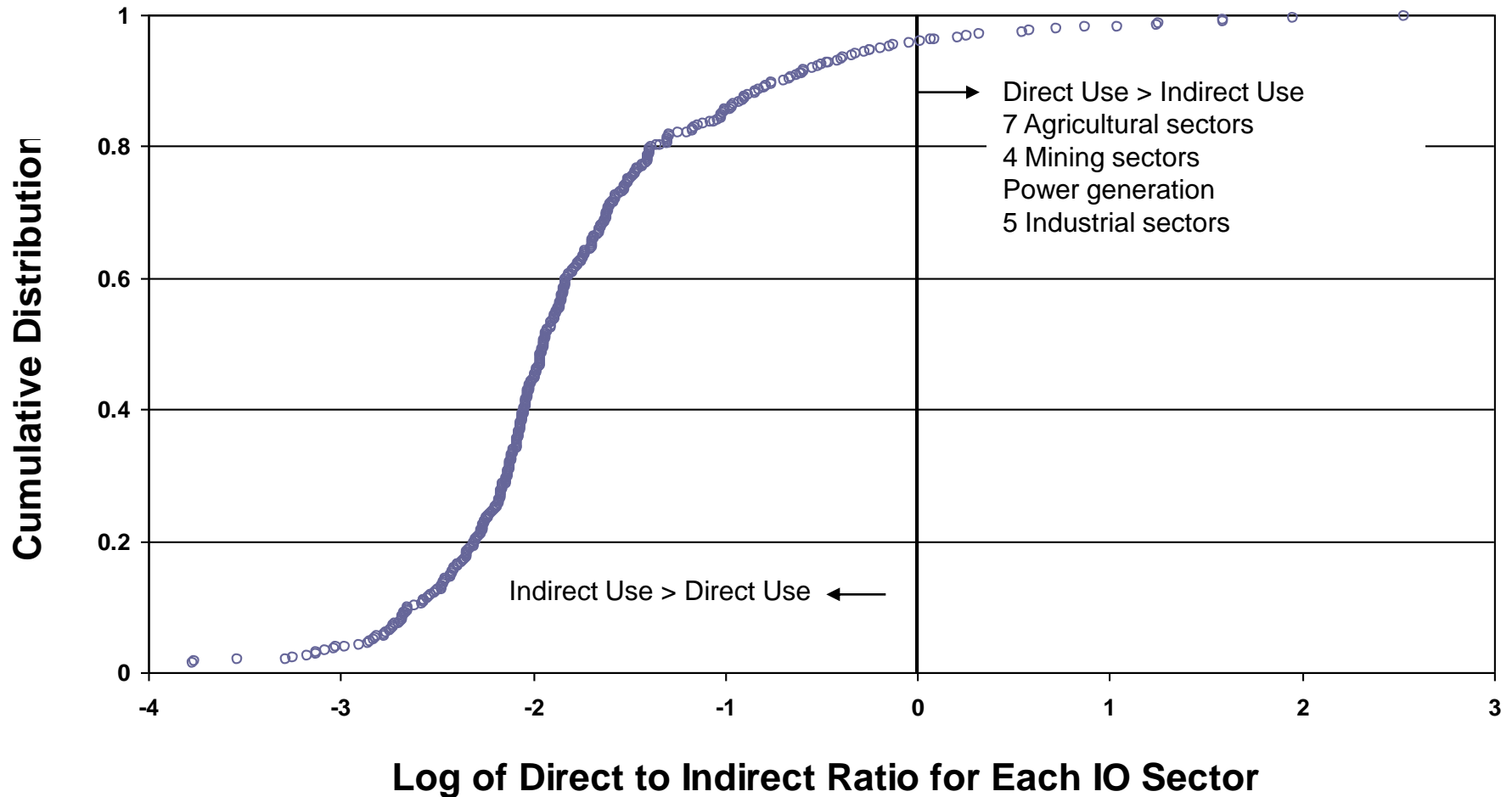
Results for 2002 US Economy



Top Water Using 10 Sectors

Sector	Total Gal / Total Output	Direct Gal / Direct Output	Indirect Gal / Indirect Output	Direct / Indirect
Grain farming	520	720	20	36
Cotton farming	520	750	39	19
Sugarcane and sugar beet farming	400	510	41	12
Tree nut farming	270	320	64	5.0
Fruit farming	250	310	57	5.4
Flour milling and malt manufacturing	170	0.044	510	0.000086
Power generation and supply	160	190	2.6	73
Wet corn milling	160	0.47	450	0.0010
Beet sugar manufacturing	140	0.035	430	0.000082
Vegetable and melon farming	140	160	49	3.3
Other animal food manufacturing	110	4.3	270	0.016
Sugar cane mills and refining	93	0.044	240	0.00018
Poultry and egg production	85	0.83	200	0.0042
Dog and cat food manufacturing	68	3.1	180	0.017
Cattle ranching and farming	65	32	110	0.29
Fiber, yarn, and thread mills	64	0.94	160	0.0059
Tortilla manufacturing	58	0.12	190	0.00062
Milk Production	54	3.1	150	0.021
Paint and coating manufacturing	53	71	18	3.9
Frozen food manufacturing	52	0.14	150	0.00091

Supply Chain Impacts



96% of sectors use more water indirectly than directly

Variability & Uncertainty

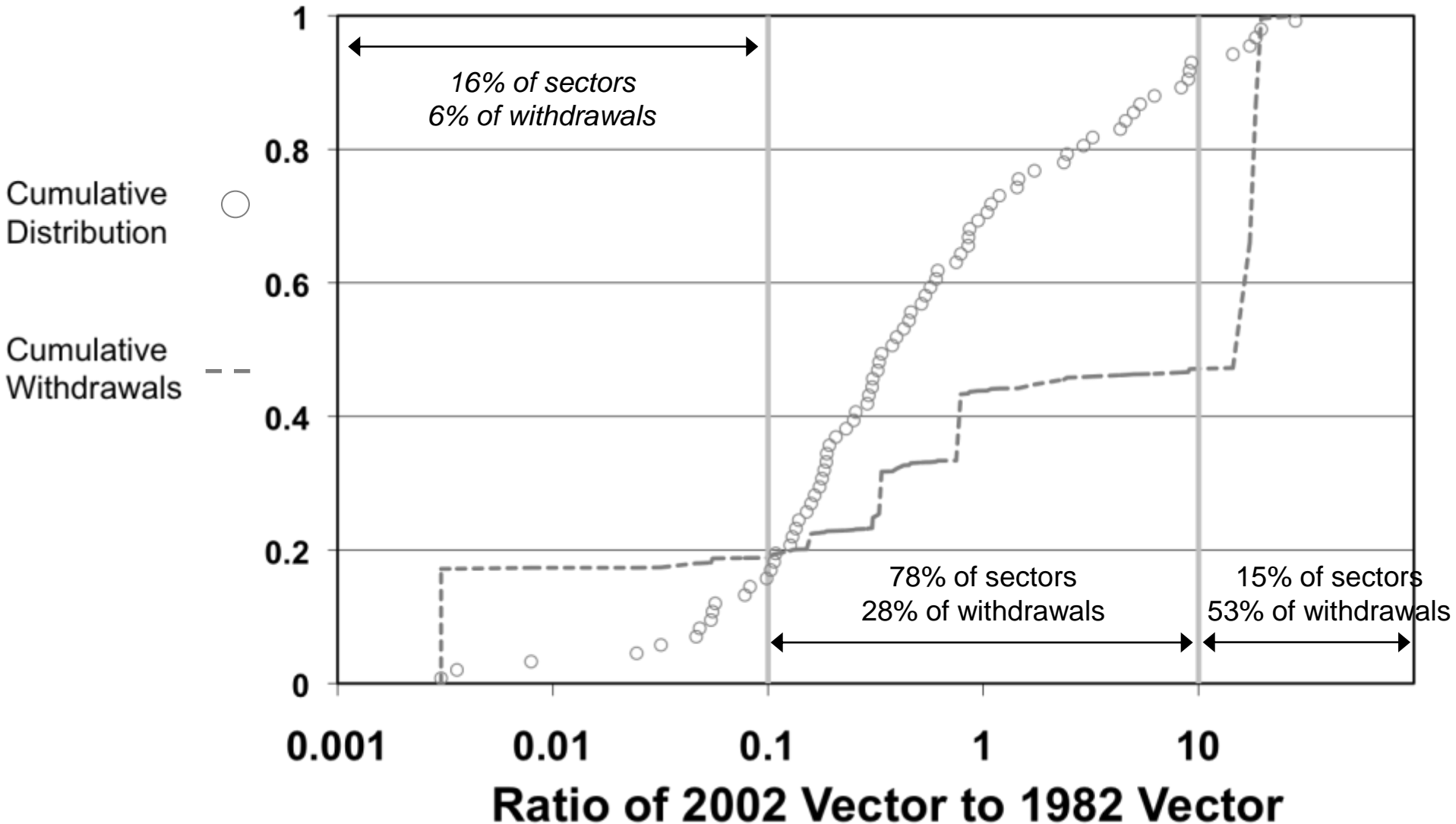
- Variability
 - Climate
 - Geography
 - Regional Industry & Economy
- Uncertainty
 - Data sources
 - Allocation
 - Reporting Error

Major Sources of Variability

Agricultural and power sectors...

IO Sector	Max: Min Ratio Withdrawal	Max State	Min State
Oilseed farming	8	NA	NA
Grain farming	58	AZ	MD, NY, PA, VA, LA
Vegetable & melon farming	44	WY	MA, LA, IN, MO
Fruit farming	67	MA	MS, NV, MD, NE
Tree nut farming	67	MA	MS, NV, MD, NE
Tobacco farming	9	FL	PA
Cotton farming	14	AZ	NC
All other crop farming	58	AZ	NY, LA
Sugarcane & sugar beet farming	8	WY	MI
Power Generation	31:0	VT	HW,ID

Comparison to 1982 Census



Summary

- Direct 2002 withdrawals 50% of 4 US largest rivers
- Agriculture, power generation, food processing major users
- A majority of water use is indirect (60%)
- A majority of sectors (96%) use more indirectly
- Quality of current water use data of concern

Recommendations

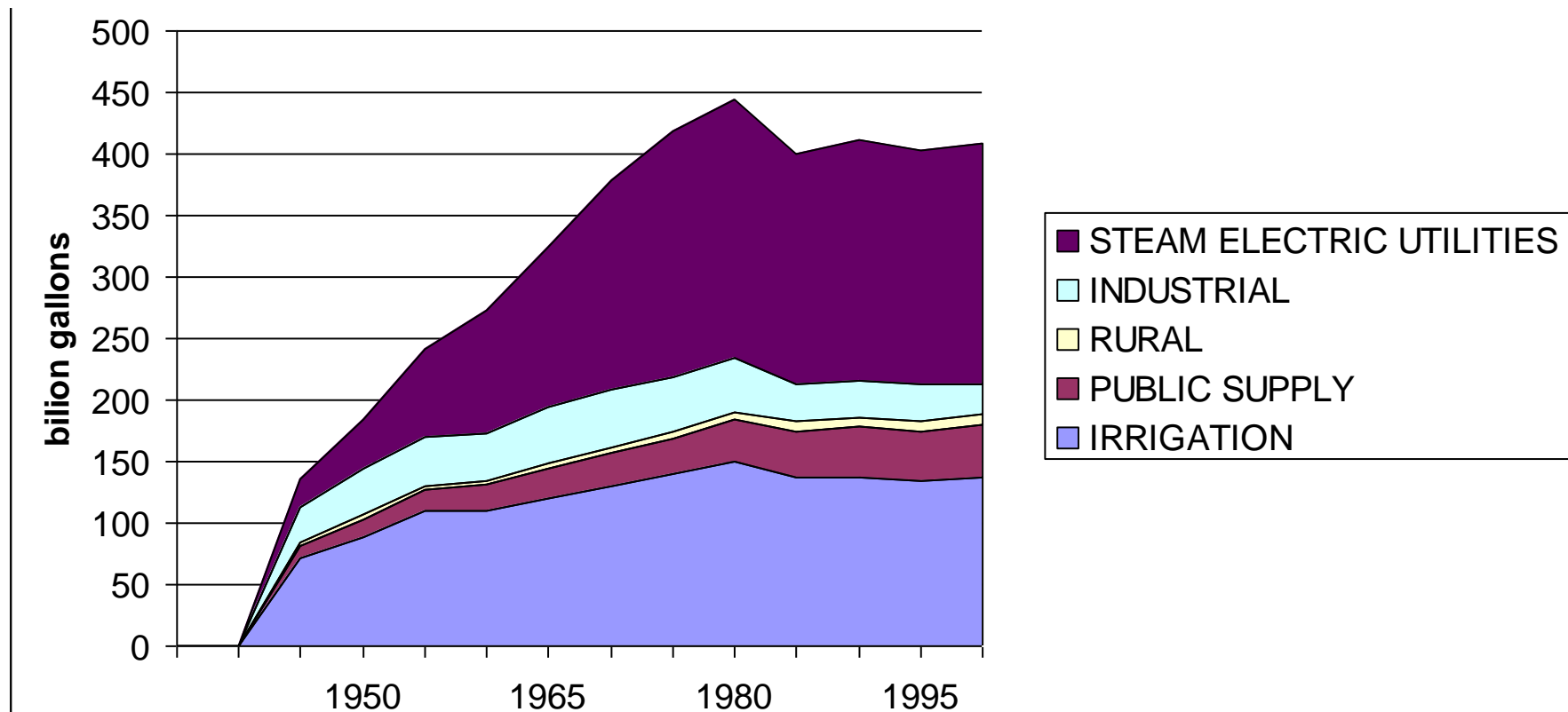
- Improve data collection
 - US Census – Industrial water use
 - USGS – Improve sector resolution
 - States – Standardize reporting and quality control
- Water LCA practitioners
 - Hybrid methods (EIO-LCA for scoping/boundary)
 - Regional models will improve applications
 - Supply chain impacts critical

Questions & Discussion

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Backup

Historical Water Withdrawals



Agricultural Data Summary

Data Source	Benchmark Year	No. of Crops Reporting		No. of Animal Products Reporting		5-Digit NAICS Coverage	IO Sectors Represented by Aggregation (14 Total)	Allocation Data Available
		Irrigated Land	Irrigation Rates	Irrigated Land	Irrigation Rates			
USDA Census of Agriculture	2002	31	0	0	0	14 sectors	7	Complete Representation of Land Use
USDA Farm & Ranch Irrigation Survey	2003	23	23	1 (all combined)	1 (all combined)	13 sectors	4	Partial Representation of Land Use

Results for 2002 US Economy

26 Sector Resolution	Total Use (bil gal)	Total Use (gal/\$)	Direct Use (bil gal)	Indirect Use (bil gal)	Direct / Indirect
Agriculture	79,000	120	57,000	22,000	2.6
Power Generation	63,000	96	63,000	180	350
Food, Beverage, & Tobacco	57,000	87	1,900	55,000	0.035
Government & Other Utilities	17,000	26	2,600	14,000	0.19
Entertainment	12,000	19	350	12,000	0.029
Info, Finance, Insurance, Real Estate	11,000	16	560	10,000	0.056
Petroleum & Basic Chemicals	10,000	15	1,500	8,500	0.18
Wholesale, Retail, & Warehousing	7,700	12	210	7,400	0.028
Services	7,100	11	150	6,900	0.022
Healthcare & Social Assistance	7,000	11	230	6,800	0.034
Construction	6,800	10	150	6,600	0.023
Forest Products & Printing	6,100	9.3	970	5,100	0.19
Textiles	6,000	9.2	31	6,000	0.0052
Transportation Vehicle & Equip	5,700	8.7	99	5,600	0.018
Pharm, Coating, & Cleaning Products	5,000	7.7	2,700	2,400	1.1
Other Services	3,000	4.6	210	2,800	0.075
Electronic & Electrical Equipment	3,000	4.6	28	3,000	0.0093
Mining	2,800	4.3	1,300	1,500	0.87
Metals	2,800	4.3	240	2,600	0.092
Plastics & Rubber	2,700	4.1	39	2,600	0.015
Transportation	2,700	4.1	210	2,500	0.084
Fabricated Metal Products	2,500	3.8	35	2,500	0.014
Education	2,400	3.6	420	1,900	0.22
Machinery Manufacturing	1,900	3	17	1,900	0.0089
Other Manufacturing	1,900	2.9	33	1,900	0.017
Non-Metallic Minerals	1,500	2.2	17	1,400	0.012