Virtual Water Accounting Concepts

Outline

- Motivation
- Basic concepts of virtual water exports and imports
- Definitions of water use
- Data needs and space and time scales
- Value intensities
- Trade data
- Relating virtual water flows to (adverse) resource impacts

Motivation

- Society has traditionally assumed that water is a freely available, abundant public good.
- But, scarcity in water resources is a recurring issue around the US and world.
- Scarcity signals that there are difficult choices, and tradeoffs that must be made between economic, social, and environmental uses
- Watersheds in the GL region are beginning to experience scarcity, primarily in the form of low summertime flows that are impacting aquatic ecosystems.
- On the other hand, the relative abundance of water in the GL region implies economic opportunity to some…

Motivation

The Great Lakes Water Resources Compact mandates

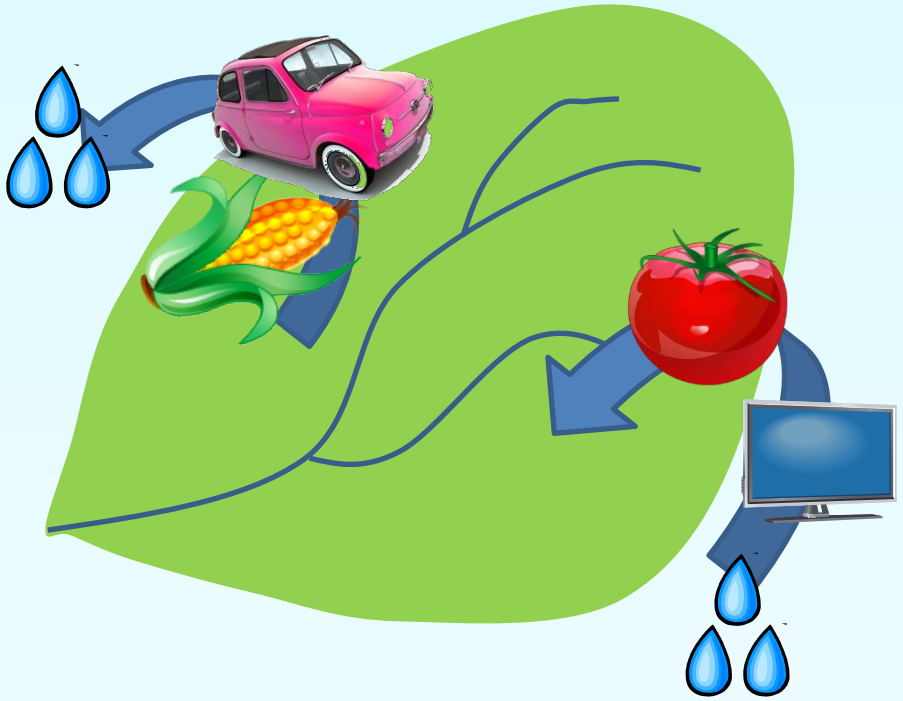
- "…management and regulation of New or Increased Withdrawals and Consumptive Uses …"
- "…ensur[ing] that…. no significant individual or cumulative adverse impacts to the quantity or quality of the Waters and Water Dependent Natural Resources …"
- "The proposed use is … based upon a…balance between economic development, social development and environmental protection…"

Motivation

- Water follows a complex and mostly hidden path through society- we use water to produce things that we need and value, like food, cars, electricity.
- Globalization has created a world that is highly connected, where economic demands create trade networks for importing and exporting goods and services.
- When these goods and services are traded from their point of origin, the water used in their creation is virtually transported with them.
  - virtual water exports impact water resources at the point of origin
  - virtual water imports offset water resource impacts at the location of import.
- Virtual water accounting offers a platform for anticipating potential adverse impacts due to overuse, assessing the value of water across water use sectors, and identifying opportunities for taking advantage of water abundance.

What is virtual water?

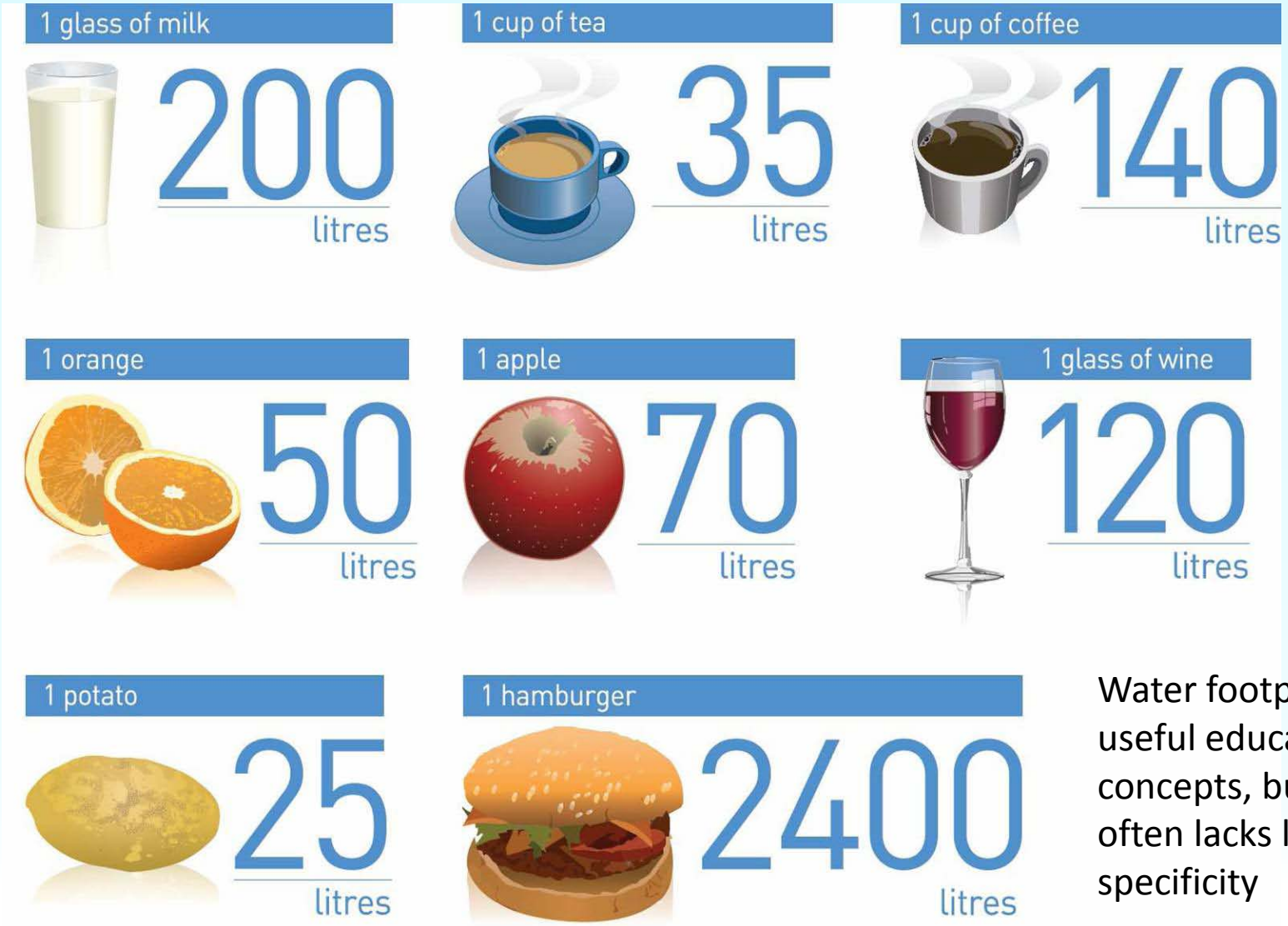
- Virtual Water is the water associated with a traded good or service, and is the water resource impact associated with the production of that good or service.
- The concept is useful for visualizing how water impacts are outsourced (or insourced) through trade, and how trade creates or substitutes for local water impacts.



- Historically, consumptive-use 'Water Footprints' have been the basis for virtual water methods.

Water footprints

http://www.sciencemediacentre.co.nz/wp-content/upload/2009/09/virtual-water3.jpg



Water footprints are useful educational concepts, but water often lacks location-specificity

Tracking water use

- Water withdrawals (*W*)
- Consumptive use (*CU*) [= water footprint?]
- Return flows (*RF*)

  $W = CU + RF$

  $CU = cW$ where c = consumptive use coefficient

- Green vs. blue water use

Consumptive use coefficients

Category	Statistic (%)		
	25th %-ile	Median	75th %-ile
Domestic & Public Supply	10	12	15
Industrial	7	10	14
Thermoelectric Power	1	2	2
Irrigation	90	90	96
Livestock	80	83	90
Commercial	8	10	15
Mining	7	10	25

Shaffer, K.H., and Runkle, D.L., 2007, Consumptive Water–Use Coefficients for the Great Lakes Basin and Climatically Similar Areas: U.S. Geological Survey Scientific Investigations Report 2007–5197, 191 p. http://pubs.usgs.gov/sir/2007/5197/

What is virtual water?

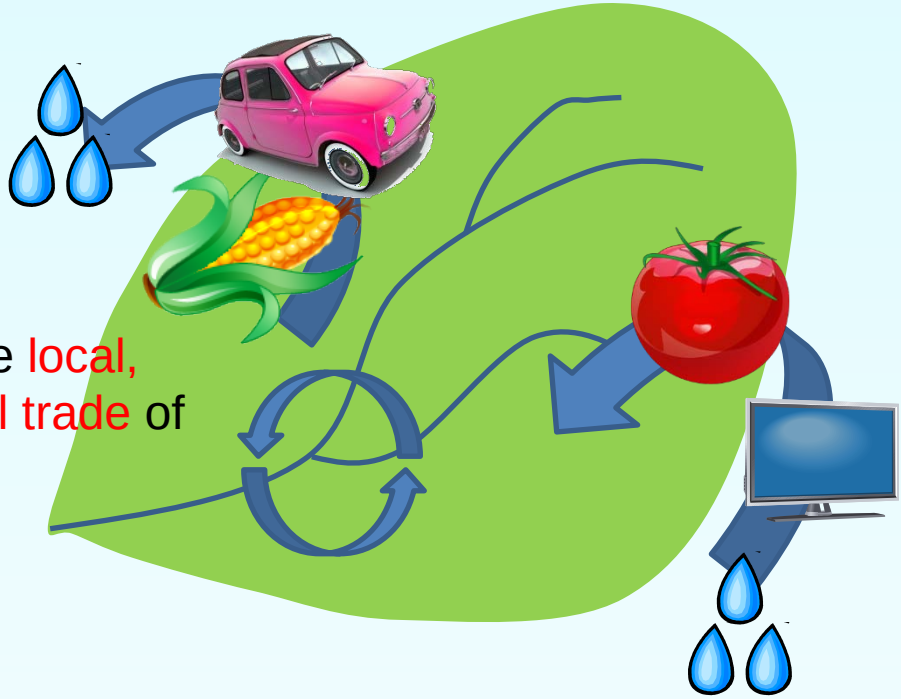
VWE is the consumptive use that occurs in an area associated with exports from the area

- Net virtual water balance

  $NVW = VWI - VWE - R$

- *NVW* allows us to determine the net consumption of water associated with goods and services exported from and imported into the watershed.

- Note that *VWI* "offsets" *VWE*

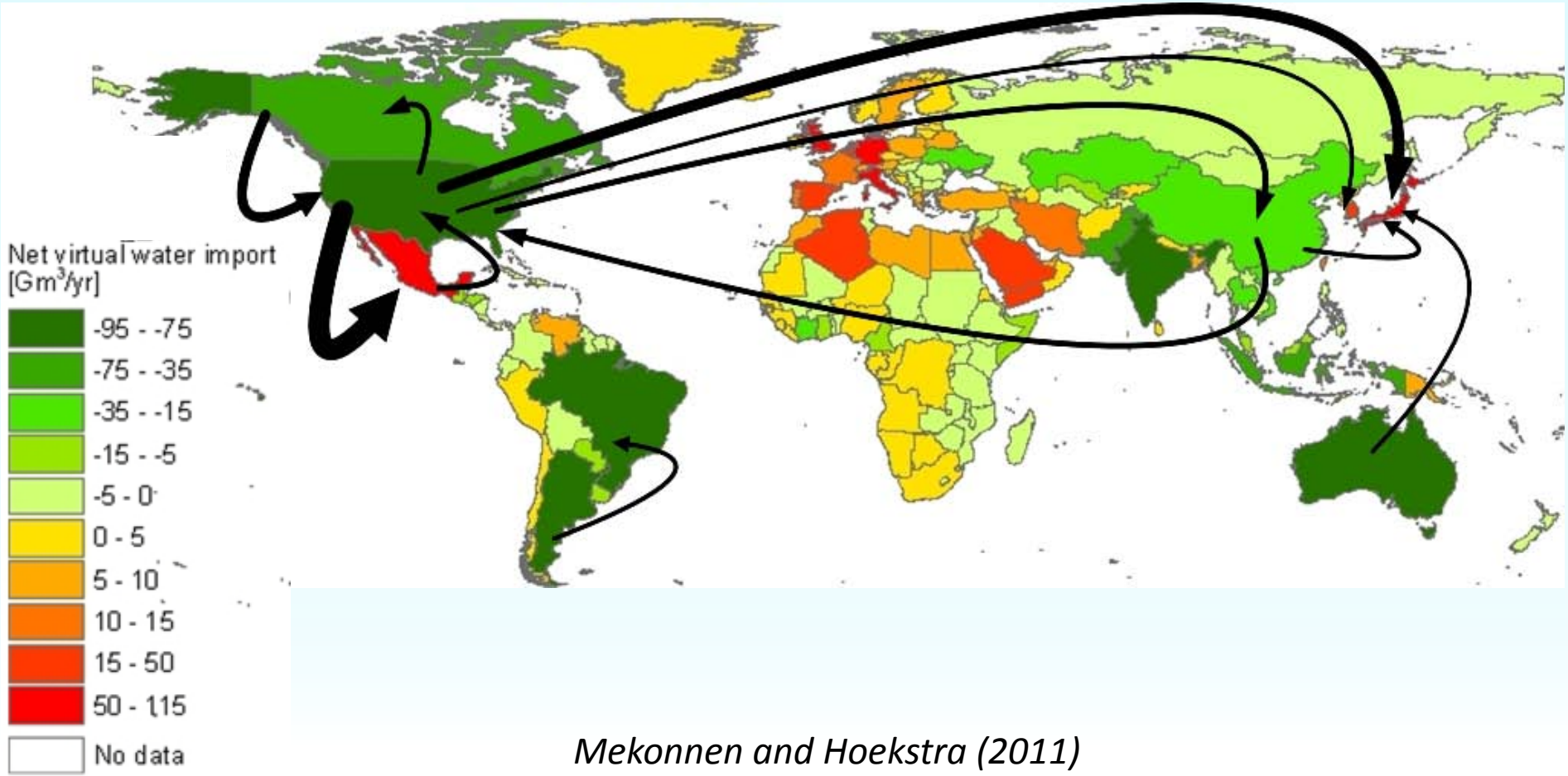


R is the local, internal trade of water

VWI is the consumptive use that occurs in the area from where imported goods and services were produced

Virtual water balance per country related to trade in agricultural and industrial products over the period 1996-2005.

The global volume of international virtual water flows in relation to trade in agricultural and industrial products averaged 2,320 billion m^3 per year during the period 1996-2005



Mekonnen and Hoekstra (2011)

http://www.waterfootprint.org/?page=files/VirtualWaterFlows

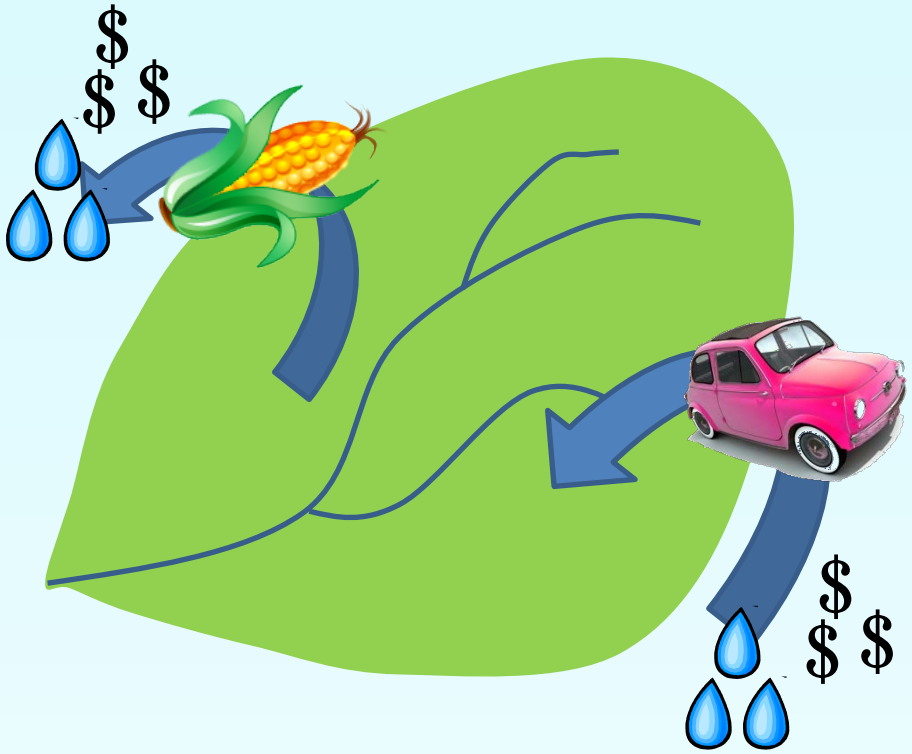
What can VW accounting tell us?

- Water volumes or flows
  - Volumes of VW exports (*VWE*): typically equal to consumptive use
  - Volumes of internally traded water (*R*)
  - Volumes of VW imports (*VWI*)
  - Net VW = *VWI* - *VWE* - *R*
- Value intensities
  - Trade data is required to track imports and exports.
  - Trade data allows us to assess VW volumes against money generated from sales and purchases of goods and services.

- Sales of corn exports: S_{corn}
- Consumptive use from production of corn: CU_{corn}
- **Value intensity of corn:**

  $\boldsymbol{VI_{corn} = S_{corn} / CU_{corn}}$

  units of $/volume



Defining value intensity

- Purchase of car imports: S_{car}
- Consumptive use from production of car: CU_{car}
- **Value intensity of car:**

  $\boldsymbol{VI_{car} = S_{car} / CU_{car}}$

  units of $/volume

What can value intensity tell us?

- Provides a metric for assessing value of a water use.
- For example, industrial water uses typically have much higher value intensities (remember, units are $/volume) than agricultural uses - why?
- Value intensities can help us weigh *where* water withdrawals make sense:
  - where water resources are scarce, it makes sense to promote water withdrawals that have a higher value
  - places where resources are abundant can absorb lower value water withdrawals

Measuring resource impacts of VW

- Metrics for measuring impacts of water withdrawals tend to focus on withdrawals relative to available supply such as "water stress" = W/Q.
- Consumptive use may be a more appropriate measure of impact - why or why not?
- Available supply should take into account the various uses of water, including ecological needs.
- For example: Michigan Water Withdrawal Assessment Tool establishes threshold depletions for avoiding Adverse Resource (ecosystem) impacts.

Depletion $D = W/Q$

D/T = depletion/threshold depletion

space- & time-scale dependent

Measuring resource impacts of VW

- Since VW exports imply that water has been removed from local water resources (identical to consumptive use) it is appropriate to compare VW exports to measures of water stress.
- VW imports tell us how much imports offset local water stress.
- And, if net VW (= import - export) is positive, net VW tells us how much trade we can shift from the import side to the export side before causing adverse impacts (and vice versa).

What are appropriate spatial scales or boundaries for VW Accounting?

- Depends on the water resources impact of interest…
- Depends on data availability…
- Watersheds are ultimately the most appropriate geographic unit, since this is the most common unit for determining water resource impacts.

What are appropriate time scales for VW Accounting?

- Depends on the water resources impact of interest…
- Depends on data availability…
- Annual data (withdrawals, flows, trade, etc.) may be the best one can do, data-wise, but may understate impacts.
- Data should account for, for example, low flow seasonality and seasonally high withdrawals or consumptive uses.

Data needs for Virtual Water Accounting

- ✓ Water withdrawals by location and use sector.
- ✓ Consumptive uses associated with water withdrawals: consumptive use coefficients by sector
- ✓ Trade data (exports and imports) by location and sector
- ✓ Geographically suitable measures of resource impacts: local water availability and local ecological needs

Trade data: IO tables

- Applied input output (IO) analysis* uses monetary transactions to quantify how various sectors of a complex economic system are mutually related to each other.

purchasing sector (demand)

processing sector (sellers)

	A	B	C	D	E	F
A	$1.38	.25	.28	.41	.27	.23
B	.45	1.21	.16	.19	.12	.24
C	.27	.38	1.38	.23	.17	.39
D	.35	.25	.25	1.53	.65	.41
E	.35	.26	.31	.39	1.28	.25
F	.38	.35	.22	.30	.21	1.32

http://www.rri.wvu.edu/WebBook/Miernykweb/new/chaptertwo.htm

*Leontief, W., 1986. Input–output Economics. Oxford University Press, New York.

Trade data: IO tables

selling ↓

purchasing →

Processing Sectors (Sellers)	Agriculture	Manufacturing	Service	Household	Exports	Output
	Purchasing Sectors (Demand, in $)			Final Demand, in $		
Agriculture	10	6	2	20	12	50
Manufacturing	4	4	3	24	14	49
Service	6	2	1	34	10	53
Household	16	25	38	1	52	132
Import	14	12	9	53	0	88
Input	50	49	53	132	88	372

http://reic.uwcc.wisc.edu/implan/

Trade data: IO tables

Processing Sectors (Sellers)	Agriculture	Manufacturing	Service	Household	Exports	Output
	Purchasing Sectors (Demand, in $)			Final Demand, in $		
Agriculture	10	6	2	20	12	50
Manufacturing	4	4	3	24	14	49
Service	6	2	1	34	10	53
Household	16	25	38	1	52	132
Import	14	12	9	53	0	88
Input	50	49	53	132	88	372

Internal trade

External trade*

* Imports and exports are parsed into trade sectors

Using value intensities to calculate VW imports

- Value intensities are compiled for each water use sector and geographic unit (units of $/volume).
- Value intensities (*VI*) and trade data allow us to indirectly determine VW imports (*VWI*) by sector:

  VWI = import trade/*VI*

  [volume/time] = [$/time]/ [volume/$]

Trade sector	Water use sector	Sector value intensity
Agriculture trade ($/yr)	Agriculture use (m^3/yr)	Agriculture VI ($/$m^3$)
Industrial trade ($/yr)	Industrial use (m^3/yr)	Industrial VI ($/$m^3$)
Commercial trade ($/yr)	Commercial use (m^3/yr)	Commercial VI ($/$m^3$)
…	…	…
…	…	…

A few other details…

- Some goods and services generated in a geographic unit are traded within that unit.
- The water consumed for these internal trades is “real,” but for purposes of estimating VW exports, we separate the internal consumption and calculate “gross VW exports.”
- Trade data exists for agricultural, industrial, commercial, mining, livestock, power production sectors: these trade data are relatively straightforward to relate to water consumption sectors.
- But is not clear how to relate residential/domestic /unaccounted use to trade data.

Putting it all together: Key concepts

- Virtual water exports = “external” consumptive use
- Virtual water imports “offset” VW exports
- Net virtual water = VW imports - VW exports
- Virtual water flows can be compared to flow-based metrics of scarcity (in the Great Lakes, primarily ecological scarcity)
- Value intensities as a way of comparing values of water uses and allow us to calculate virtual water imports.
- The next leap forward: combining virtual flows-ecological scarcity-value intensity to assess tradeoffs in allocating water uses…