Water in the Economy in Arizona Cities

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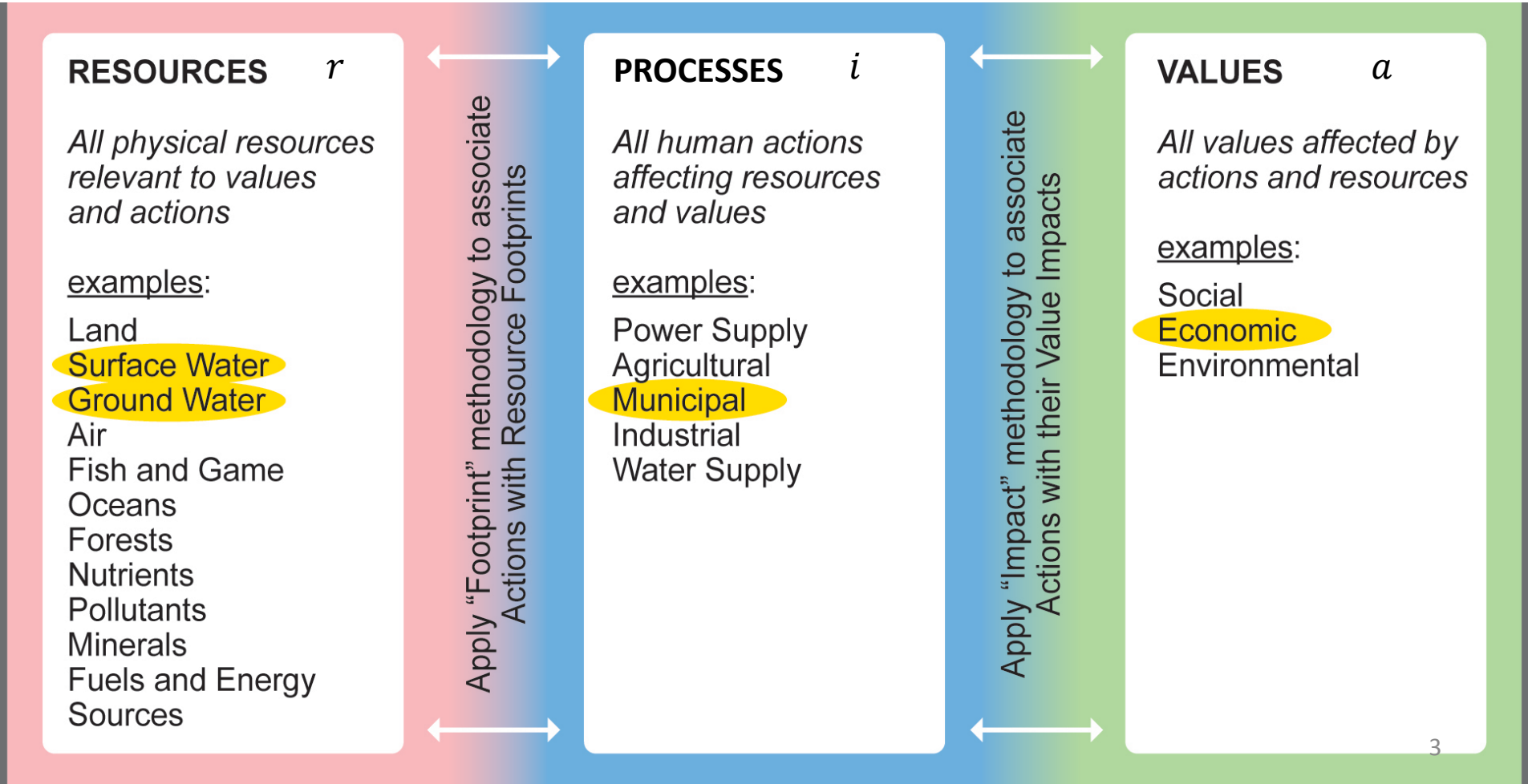
How to cope with Water Scarcity?

1. Technology, efficiency, and reuse (expensive)?
2. Curtail economic growth (too expensive)?
3. Political reallocation of water to most valuable uses (who decides)?
4. Economic reallocation of water resources using prices and water rights (political barriers and high transaction costs)?
5. Compromise our social, environmental, or economic values?
6. **<u>Outsource largest and least valuable water uses?</u>**

What are the values of water, to whom, how do we assess them in relation to hydrology, and how are we currently using #6 to solve the problem? A Complex Systems problem…

Three types of networks intersect at a specific process node in a true Coupled Natural-Human System network:

- resource production (+ or -)
- trade or exchange (money, goods, services)
- value production (+ or -)



Embedded Resource Impact Accounting (ERA): A network theory for complex CNH's

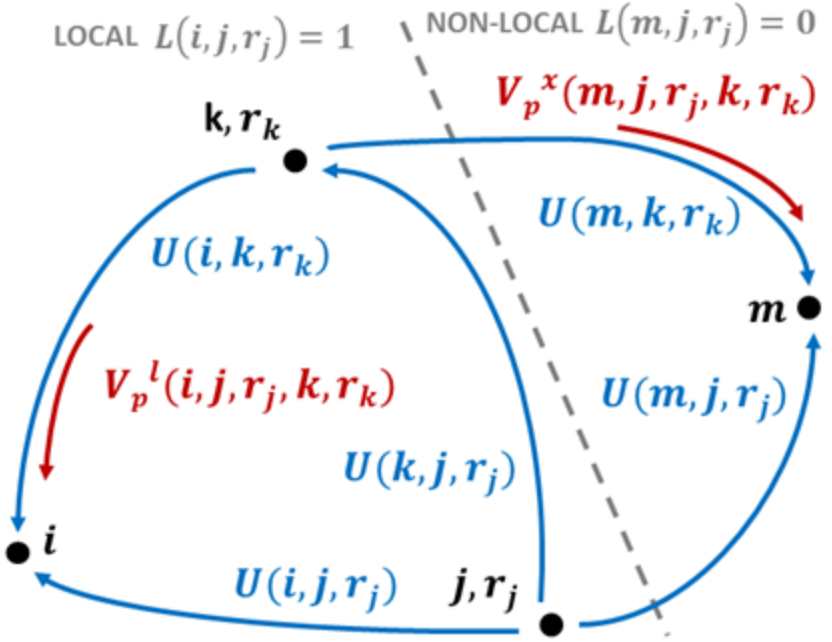
Net Systemic Impact (footprint) of a Process, E: the sum of the Direct (U) and indirect (V) network impacts of a process on a stock of interest, conditioned on a local/external (*l*/*x*) boundary

$$E = U^{l} + U^{x} + V^{l}_{IN} - V^{l}_{OUT} + V^{x}_{IN} - V^{x}_{OUT}$$

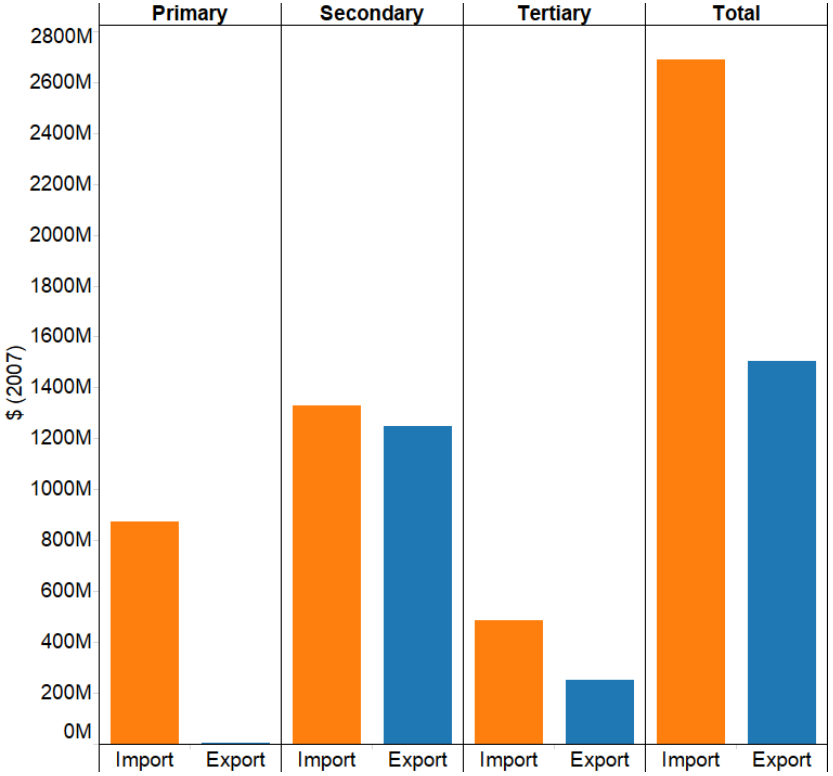
"Virtual Water" (Allan, 1993) is a special single-type network case of ERA. ERA is itself a special case of I/O and LCA, which are also network concepts.

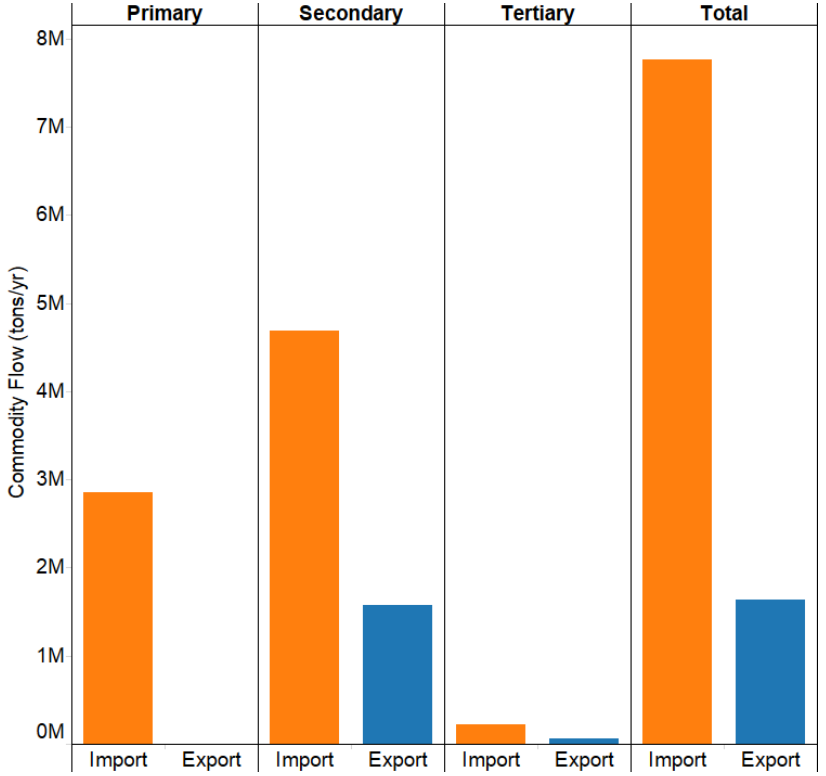
The foundation of ERA is the *partial embedded resource impact* V_p; the sum across intermediaries *k* and r_k is the net indirect impact *V*

$$V_p(i,j,r_j,k,r_k) = \frac{U(i,k,r_k)}{\sum_n U(n,k,r_k)} * U(k,j,r_j)$$



Commodity Inputs and Output By Distance



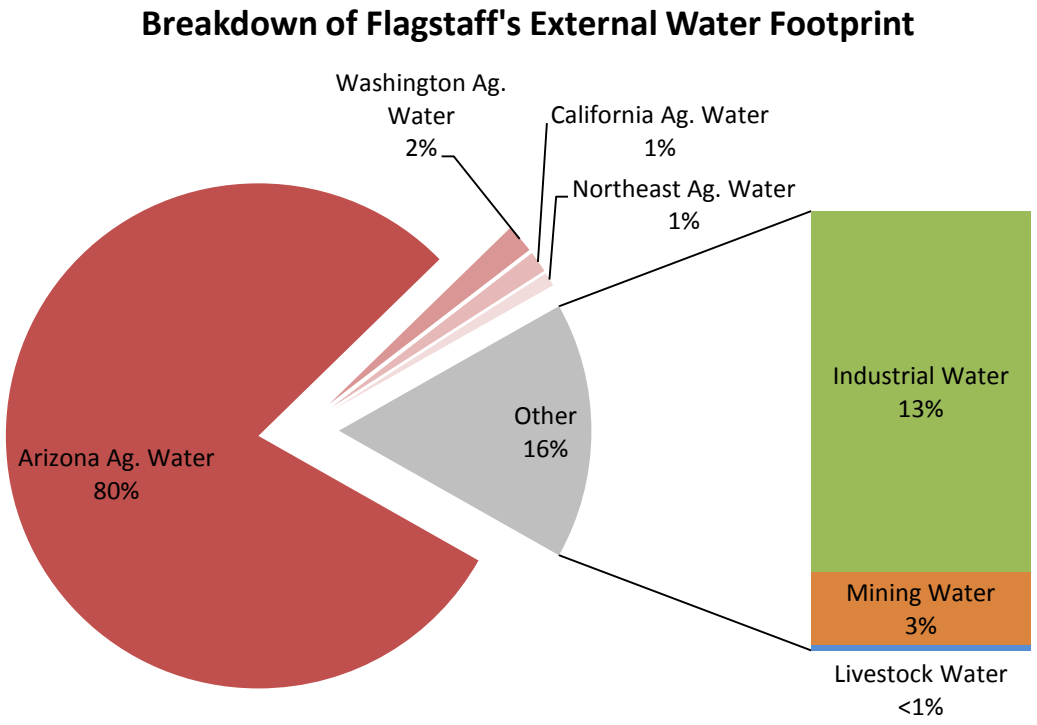


Trade Distance (mi)	Average Distance (mi)	Standard Deviaton	Frequecy of Shipment Distance
0-25	20	0	12%
26-299	237	71	11%
300-1000	615	214	40%
1001-1500	1,455	110	24%
1501+	1,915	285	14%

Trade Distance (mi)	Average Distance (mi)	Standard Deviaton	Frequecy of Shipment Distance
0-25	17	6	14%
26-299	246	71	8%
300-1000	574	150	25%
1001-1500	1,395	164	26%
1501+	2,518	784	26%

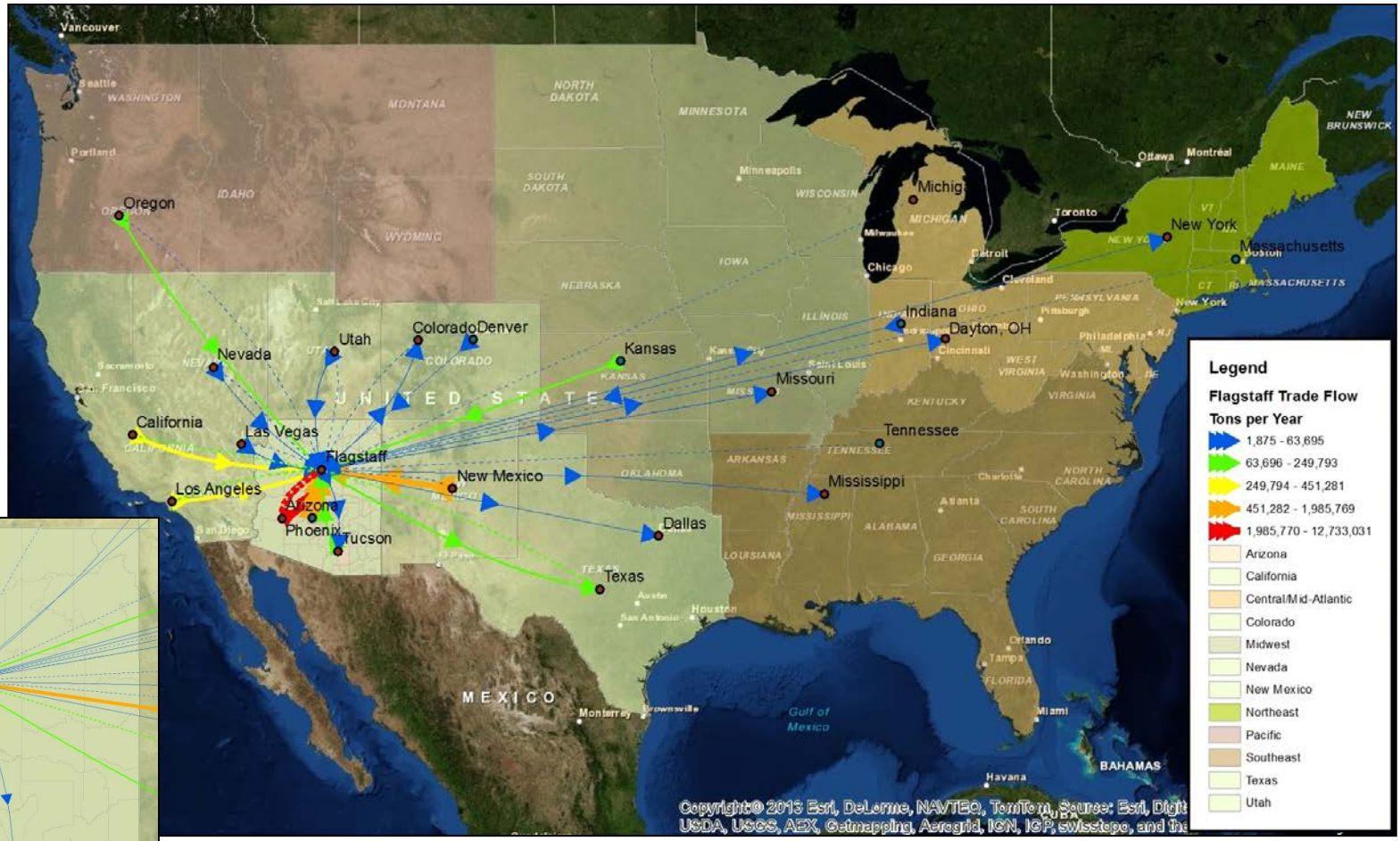
Flagstaff Virtual Water Imports

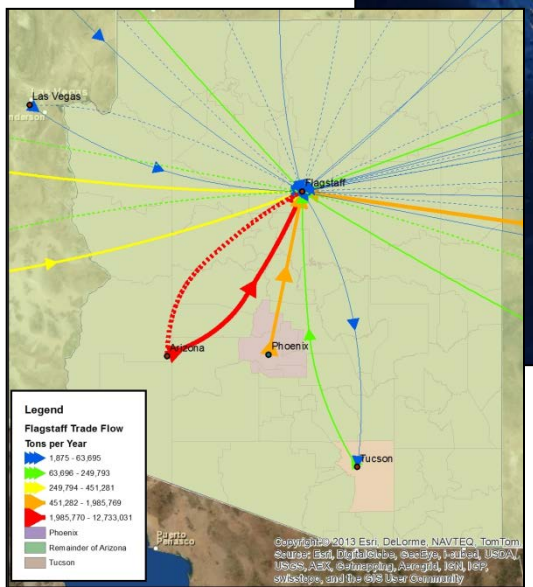
State	Water Import ac-ft/year	% of Total
AZ	50,185	93.0%
WA	1,103	2.0%
CA	998	1.8%
TX	526	1.0%
LA	410	0.8%
SC	238	0.4%
IN	130	0.2%
OH	66	0.1%
MI	60	0.1%
CO	59	0.1%
OR	53	0.1%
IL	24	0.0%
NV	24	0.0%
TN	22	0.0%
NM	19	0.0%
WV	14	0.0%
GA	14	0.0%
NY	4	0.0%
PA	4	0.0%
MO	3	0.0%
WI	3	0.0%
MA	2	0.0%
MN	2	0.0%
UT	2	0.0%
KS	1	0.0%
Total	53,966	



Economy Sector	Import Value (2007 $)	Embedded Water (acre-feet)	Embedded Water Value ($/gallon)
Primary	$875,432,388	48,559	$0.06
Secondary	$1,327,485,470	4,937	$0.83
Tertiary	$487,343,881	501	$2.99

Visualizing the Flow of Embedded Resources in and out of Flagstaff, AZ

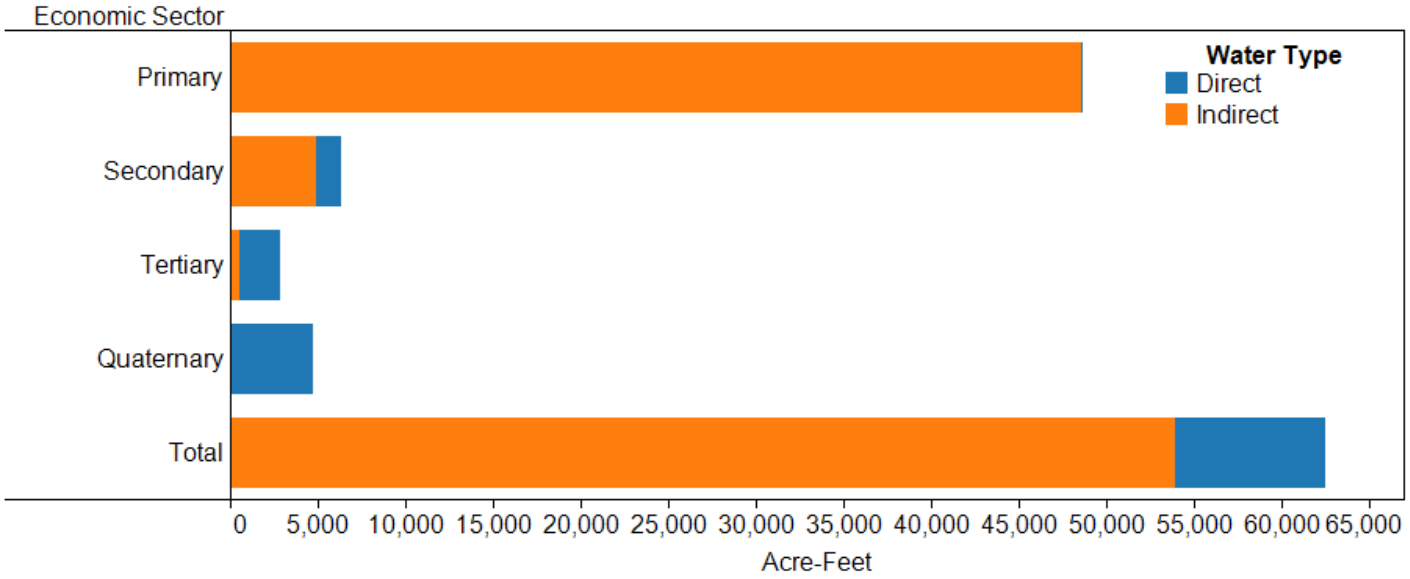




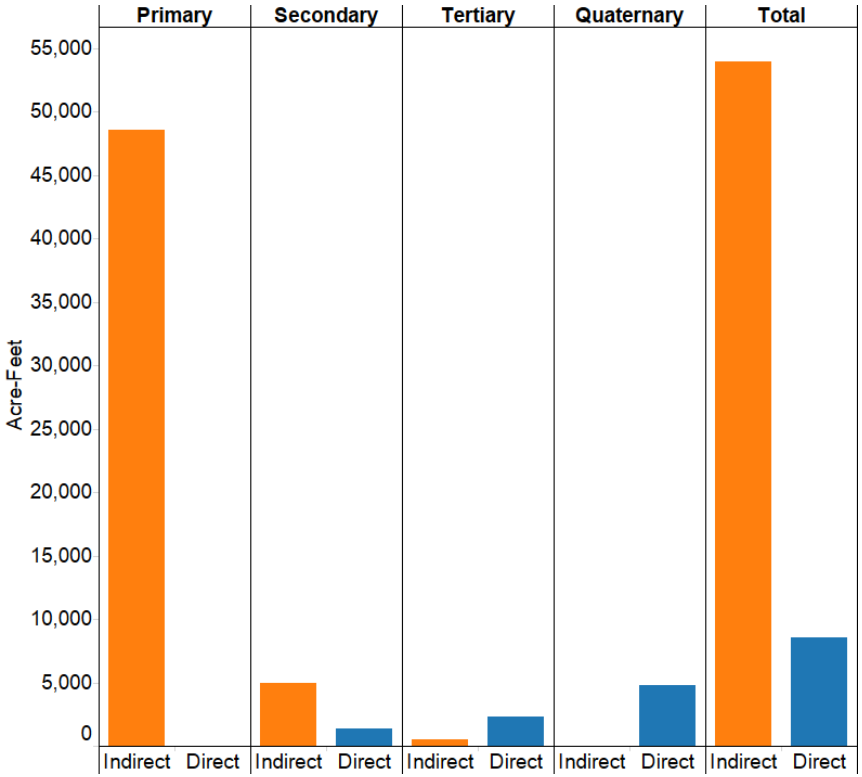
- The majority of the trade flow in and out of Flagstaff is with neighboring or nearby states
- Within AZ, Flagstaff's trade is primarily with rural areas outside of the metropolitan areas.

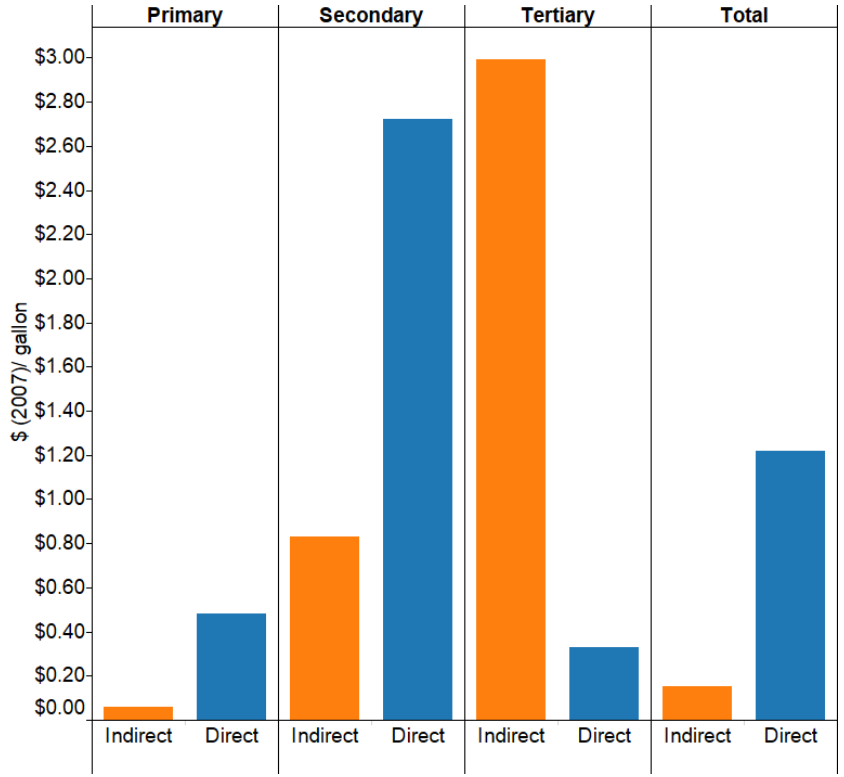
Flagstaff Water Footprint By Economic Sector

- Flagstaff's indirect water consumption (53,996 ac-ft per year) occurs in lower economic sectors
  - Resource intensive industries: agriculture
  - Lower value intensity
- Flagstaff's direct water consumption (8,553 ac-ft per year) supports higher level economic sectors
  - Less resource intensive: Education, finance, high value manufacturing
  - Higher value intensity



Value Intensity of Flagstaff Water By Sector and Type





- Flagstaff's indirect water demand more than 6x greater than direct water consumption
- Value Intensity of Flagstaff's direct consumption highest in secondary sector
- Value Intensity of Flagstaff's indirect water demand highest in tertiary sector
- Overall, Flagstaff imports lower value water (indirect) and exports water at higher value (direct)

Multiple Values of Water for Arizona Cities

Resource Stock:

Arizona Surface Water

Processes:

Arizona Cities

Values:

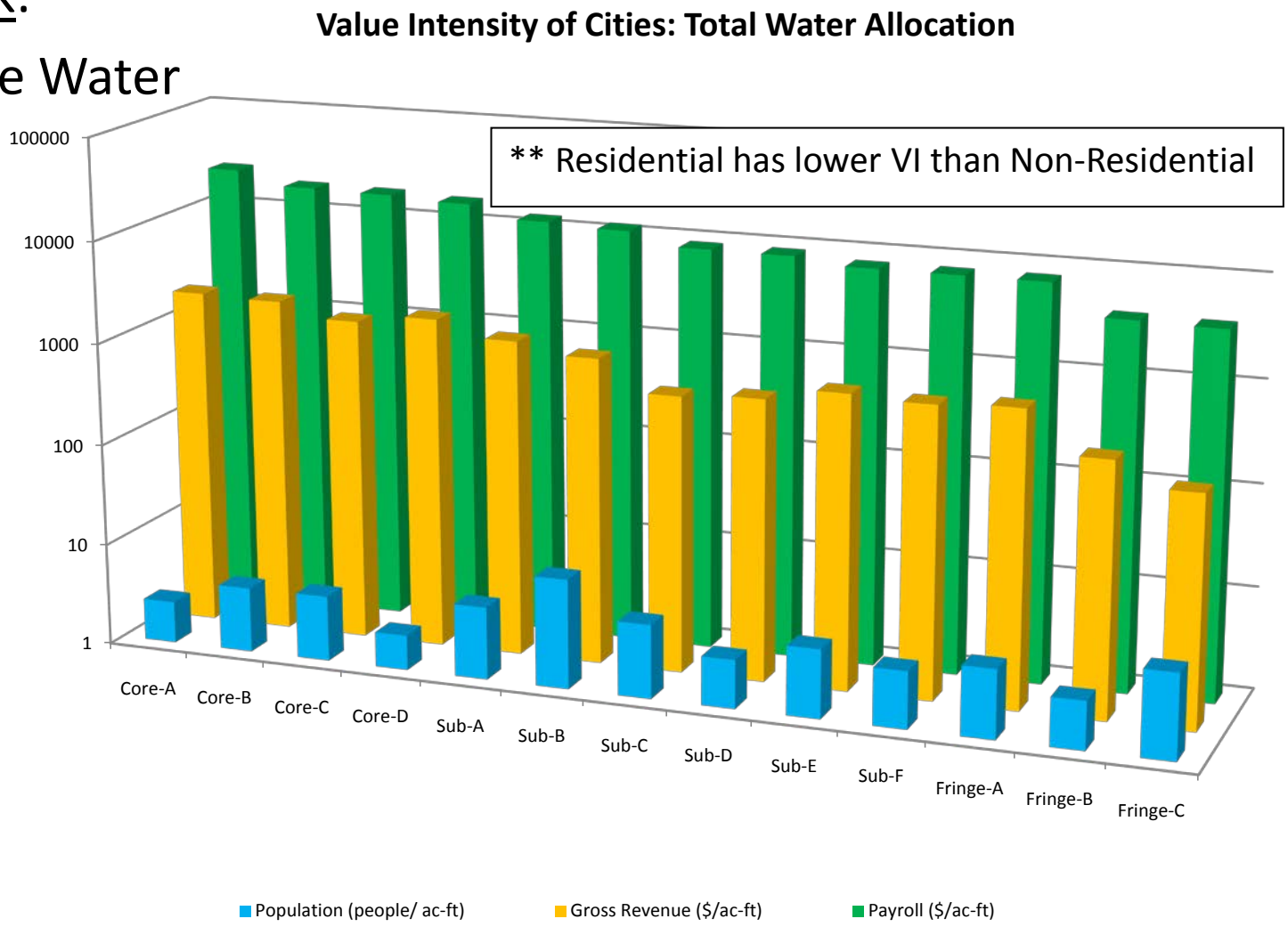
State Tax

Local Tax

People

Revenue

Payroll



DATA SOURCE: U.S. Economic Census available at http://factfinder2.census.gov, and in ADWR and municipal annual reports not available in public databases.