Electricity Generation Mix by US Industrial Sectors

Disaggregating Electricity Generation and Modeling Interstate Transfers

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Why Disaggregate?

- Primary contributor to environmental impact is electricity generation
- Impacts by generation type varies a lot
  - e.g. Hydro versus coal
- This variation should be reflected in LCA results
- For example: Aluminum manufacturing
  - Industry sector has emission numbers reduced due to plants in WA, which has 80% hydroelectric generation

Currently in LCA

- Use aggregate US generation mix to calculate emissions, GWP, etc.

Net Electricity Generation by Energy Source, 1999

Source	Generation, %
Coal	50.99%
Petroleum	3.22%
Gas	15.31%
Nuclear	19.72%
Hydroelectric	8.32%
Other	2.41%

Disaggregate Results

- Rather than a single sector:
  "Electric services (Utilities)"
- Have multiple electricity sectors:
  "Electric services (Utilities, Coal)"
  "Electric services (Utilities, Nuclear)"
  etc.
- Each industrial sector would receive a specific mix of these disaggregated electricity sectors

Making It Happen

- Data is not readily available
  - Need complete facility-level transaction data for all US industrial sectors
  - No central repository of this data
  - Economic data not necessarily a good estimate

- Instead, assign a specific generation mix to each industrial sector using:
  1. “Locations” of industry sectors from BEA
  2. State generation mixes from DOE

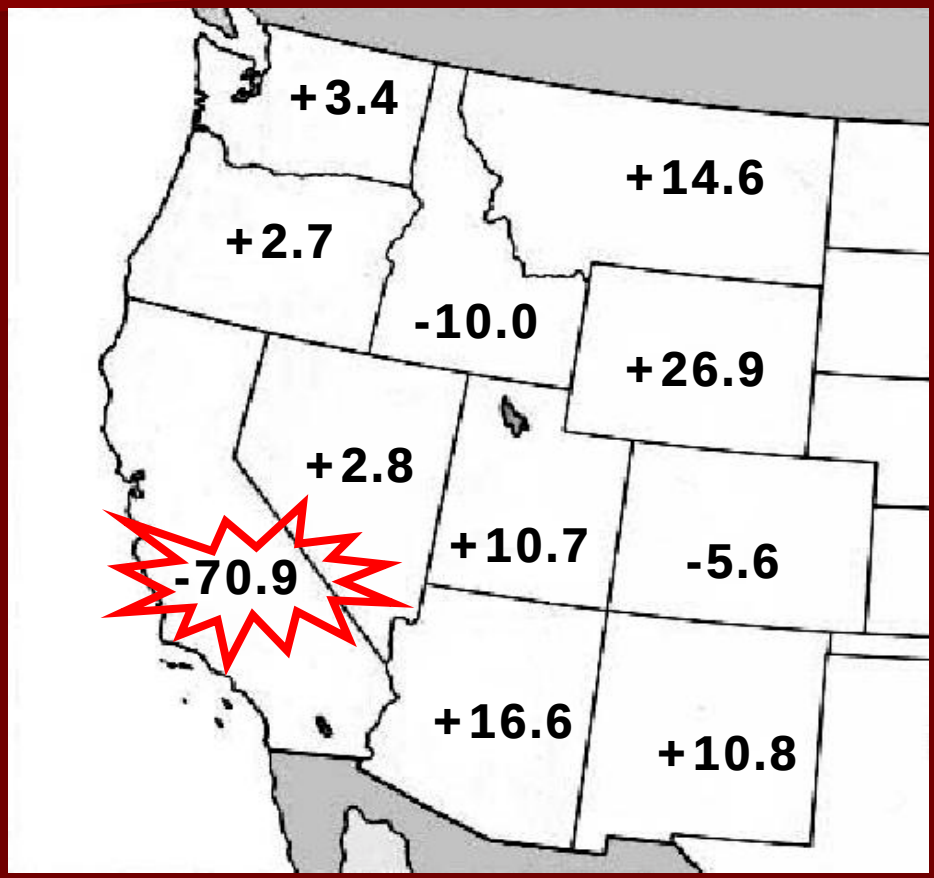
Sector Allocation to States

- Need percentage of each industry sector located in each state
  - Available using a tool developed at Carnegie Mellon by Iavor Kostov and Scott Matthews
- Economic Census location data from BEA used for placement
  - Then uses number of employees and shipments as measures of size and intensity to weight various sectors in various states

Include Interstate Trading

- Lots of electricity transfer in the United States, especially following deregulation in 1996
- Currently, interstate electricity transfer ignored, but it's a big part of the market
  - 30% of California power is imported
  - West Virginia exports 60% of theirs
- These numbers have a significant impact, so new generation mixes are created for each state

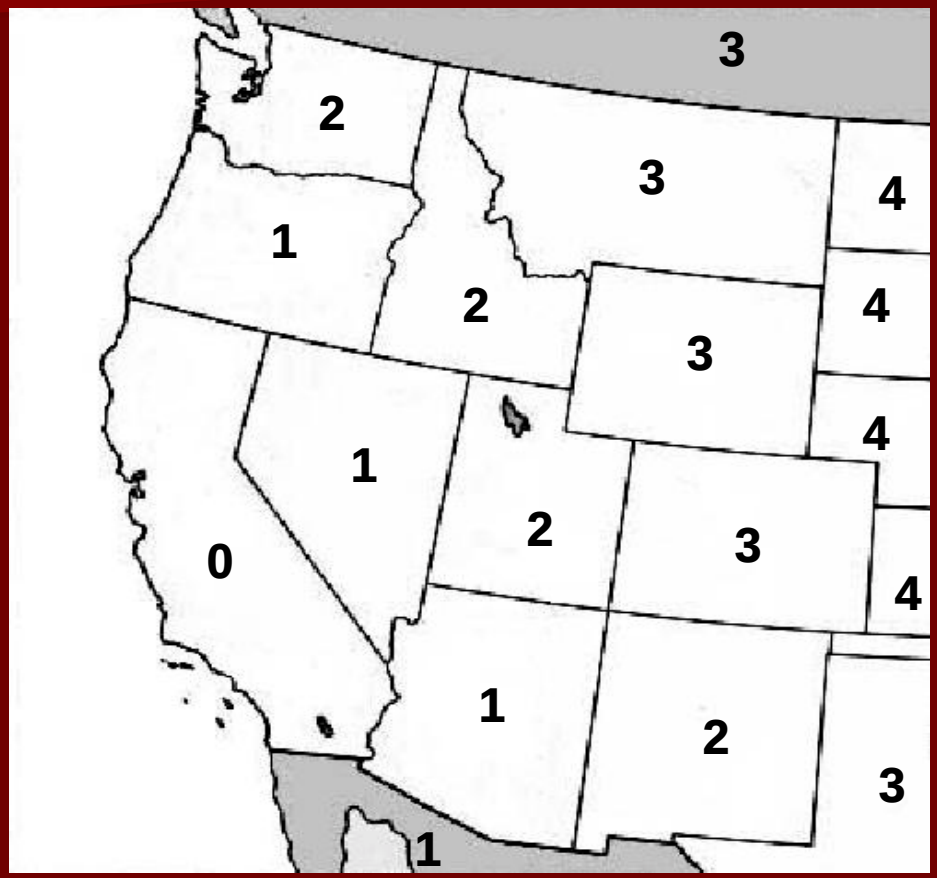
Western US: Net Imports (TWh)



Model: Linear Optimization

- Using 2 large matrices (23 x 28), find out where imports likely came from by minimizing distance (hops) traveled
- Classic transportation/distribution cost minimization problem
- This still isn't what is *actually* happening on the grid, but it's a pretty good estimate

State “Hops” for California



Complete US Hop Count

	CA	CO	CT	DC	DE	FL	GA	IA	ID	IL	LA	MA	MD	ME	MI	MN	MO	MS	MX	NC	NJ	NV	NY	OH	OR	VA	VT	WI
AL	6	4	6	4	4	1	1	3	5	3	2	6	3	8	4	5	2	1	4	2	5	6	5	3	7	2	6	4
AR	4	2	6	4	5	3	2	2	4	2	1	6	4	8	4	3	1	1	2	2	6	4	5	3	2	3	6	3
AZ	1	1	9	6	7	6	5	3	2	4	3	9	6	11	5	4	3	4	1	5	8	1	8	5	3	5	9	4
CN	3	3	2	4	3	7	5	2	1	2	5	2	3	1	1	1	3	5	99	4	2	2	1	2	2	4	1	1
IN	7	4	4	3	3	4	3	2	5	1	4	4	3	6	1	3	2	3	5	3	3	6	3	1	6	2	4	2
KS	4	1	6	4	5	4	3	2	3	2	3	6	4	8	4	3	1	3	3	3	5	3	5	4	4	3	6	3
KY	6	3	4	2	3	3	2	2	5	1	3	4	2	6	2	3	1	2	4	2	3	5	3	1	6	1	4	2
MT	3	2	8	8	7	7	6	2	1	3	5	8	7	10	4	2	3	5	4	6	7	2	7	5	2	6	8	3
ND	4	3	8	8	7	7	6	2	2	3	6	8	7	10	3	1	3	5	5	6	6	3	6	4	3	6	8	2
NE	4	1	6	4	5	4	3	1	2	2	3	6	4	8	3	2	1	3	3	3	5	3	5	3	3	3	6	2
NH	12	8	2	5	4	9	7	7	9	6	8	1	4	1	5	7	6	7	8	6	3	10	2	4	11	5	1	6
NM	2	1	8	5	7	6	4	3	2	3	2	8	7	10	5	4	2	3	1	4	7	2	7	6	3	6	8	4
OK	3	3	6	5	6	4	3	2	3	2	2	6	5	8	4	3	1	2	2	3	7	3	5	3	4	4	6	3
PA	8	5	2	2	1	5	4	4	7	3	5	2	1	4	2	4	3	4	7	3	1	8	1	1	8	2	2	3
RI	11	8	1	5	4	9	8	7	9	6	8	1	4	3	5	7	6	8	10	6	3	10	2	4	10	5	2	7
SC	8	5	6	3	4	2	1	4	6	4	4	6	3	8	5	6	3	3	6	1	5	8	5	4	8	2	6	5
SD	4	2	7	6	6	6	5	1	2	2	5	7	6	9	3	1	2	4	4	5	6	3	6	4	3	5	7	3
TN	5	3	5	2	4	2	1	2	4	2	2	5	2	7	3	3	1	1	3	1	4	5	4	2	5	1	5	3
TX	3	2	7	7	6	4	4	3	4	3	1	7	4	9	5	4	2	2	1	3	6	3	7	5	4	3	7	4
UT	2	1	8	6	7	6	5	3	1	4	3	8	6	10	5	4	3	4	2	5	7	1	7	5	2	5	8	4
WA	2	3	10	8	8	7	7	4	1	5	5	10	8	12	6	4	4	6	3	7	8	2	9	6	1	7	10	5
WV	7	4	3	2	2	4	3	3	5	2	4	3	1	5	2	4	2	3	6	2	2	6	2	1	7	1	4	3
WY	3	1	8	6	6	6	5	2	1	3	4	8	5	10	4	2	2	4	3	5	6	2	6	4	2	4	8	3

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CN	3	3	2	4	3	7	5	2	1	2	5	2	3	1	1	1	3	5	99	4	2	2	1	2	2	4	1	1
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SD	4	2	7	6	6	6	5	1	2	2	5	7	6	9	3	1	2	4	4	5	6	3	6	4	3	5	7	3
TN	5	3	5	2	4	2	1	2	4	2	2	5	2	7	3	3	1	1	3	1	4	5	4	2	5	1	5	3
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WY	3	1	8	6	6	6	5	2	1	3	4	8	5	10	4	2	2	4	3	5	6	2	6	4	2	4	8	3

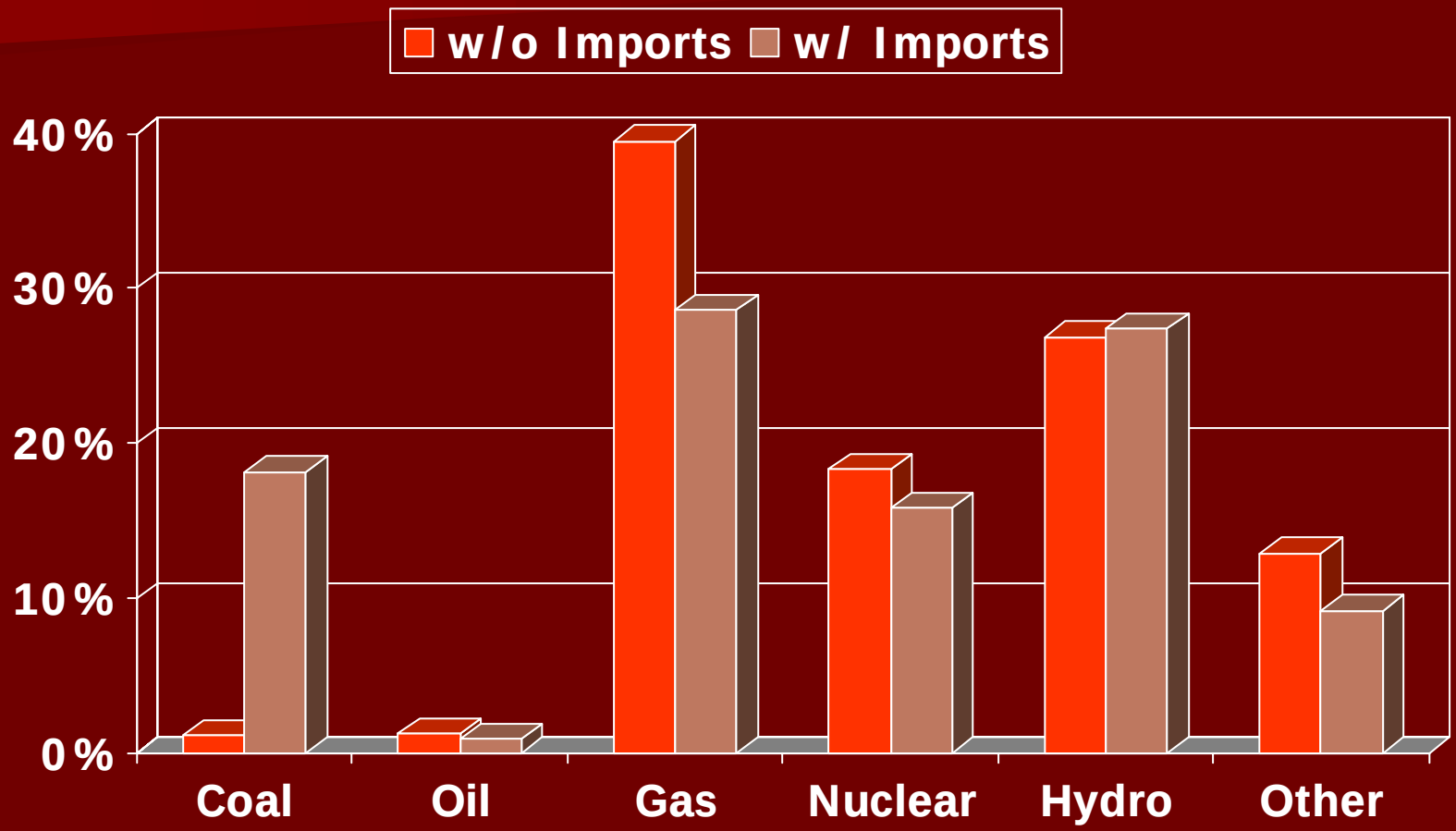
Completed Optimization, Showing Electricity Transactions in TWh

	CA	CO	CT	DC	DE	FL	GA	IA	ID	IL	LA	MA	MD	ME	MI	MN	MO	MS	MX	NC	NJ	NV	NY	OH	OR	VA	VT	WI	
AL						24	6											3											33
AR																		4											4
AZ	16																												16
CN			13									1		3									5				0	12	34
IN										5					1									8					14
KS		1															1												2
KY				2																0						7			9
MT	3								9													0			2				14
ND																17												2	19
NE		1						1																				0	3
NH												5																	5
NM	9																		1										11
OK																	1	2											3
PA				8	4							1									4								16
RI			0																										0
SC																				4									4
SD								3																					3
TN																				0									0
TX											1								0										1
UT	2																												2
WA	17																												17
WV													14											22		20			56
WY	23	3																											26
	70	5	13	10	4	24	6	5	9	5	1	8	14	3	1	17	2	10	1	5	4	0	5	30	2	27	0	14	

Generating the Generation Mix

- Have the % of imports for each importing state
  - Example: CA imports 30%
- Have the % of that imported amount that came from each exporter
  - AZ: 34%, MT: 3%, NM: 19%, UT: 4%, WA: 36%
- Know the % mix of the amount from each importer
  - Arizona: 45% Coal, 10% Gas, 35% Nuclear, 10% Hydro
- Multiply these 3 sets of percentages, normalize with existing generation mix to get the new values

The Next Generation (Mix) in CA



Electricity Allocation to Sectors

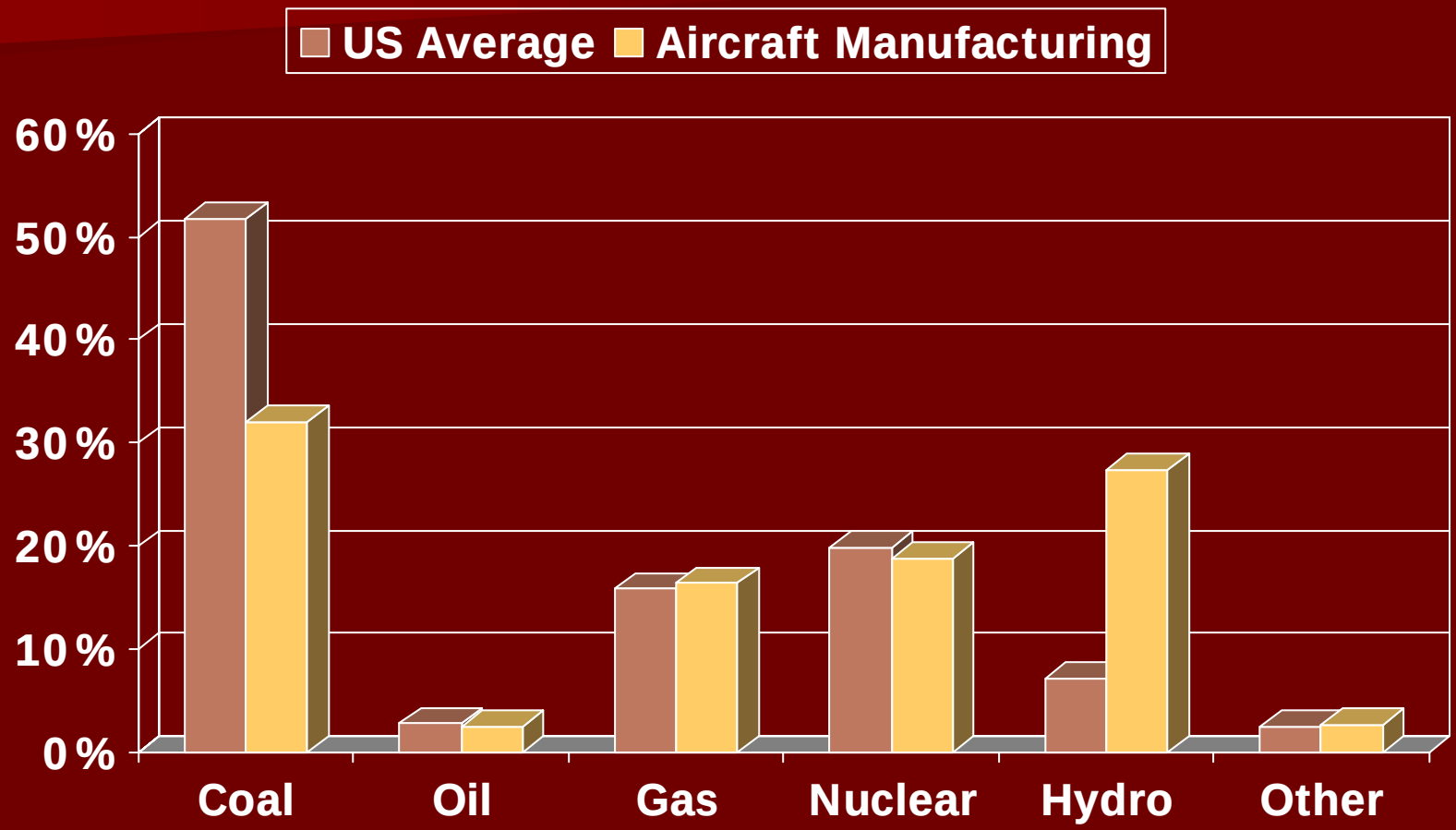
- Now, apply each state's generation mix to the percentage of all the industrial sectors in the state
  - 20% of all widgets are manufactured in CA, so 1/5 of the widget sector will have CA's generation mix
- Then sum the generation types across all sectors and states
  - Each sector now includes part of the generation mix for each state it's located in

Results of Modification

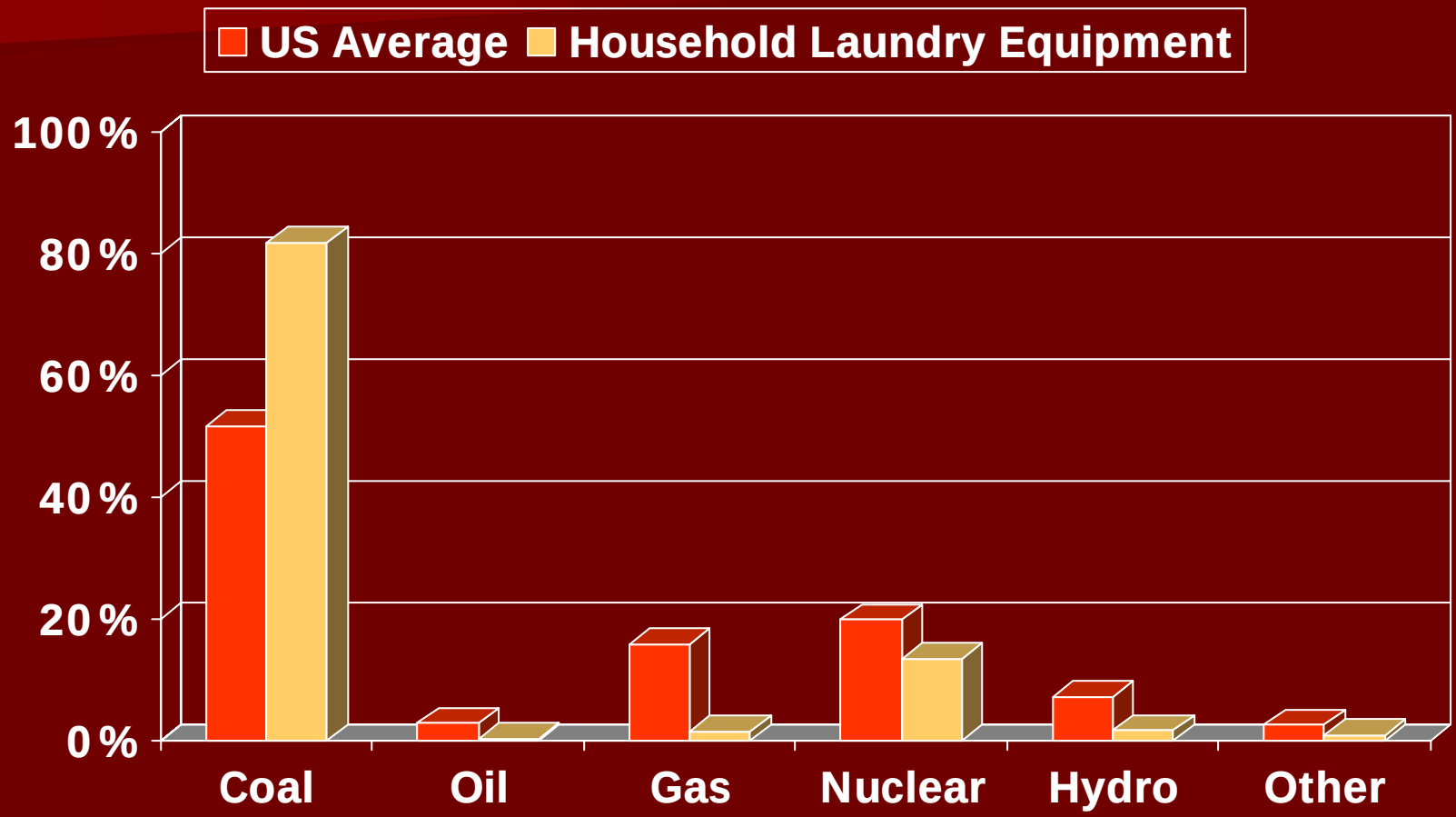
Description	Coal, %	Gas, %	Oil, %	Hydro, %	Nuclear, %
Household laundry equipment manufacturing	**83**	2	0	2	13
Oil and gas field machinery and equipment	41	**44**	1	2	10
Jewelry and silverware manufacturing	23	34	**14**	9	16
Aircraft manufacturing	30	16	3	**31**	16
Cellulosic organic fiber manufacturing	49	3	2	2	**41**

Industries with the highest specific electricity generation mix values (by energy source) in the U.S. economy

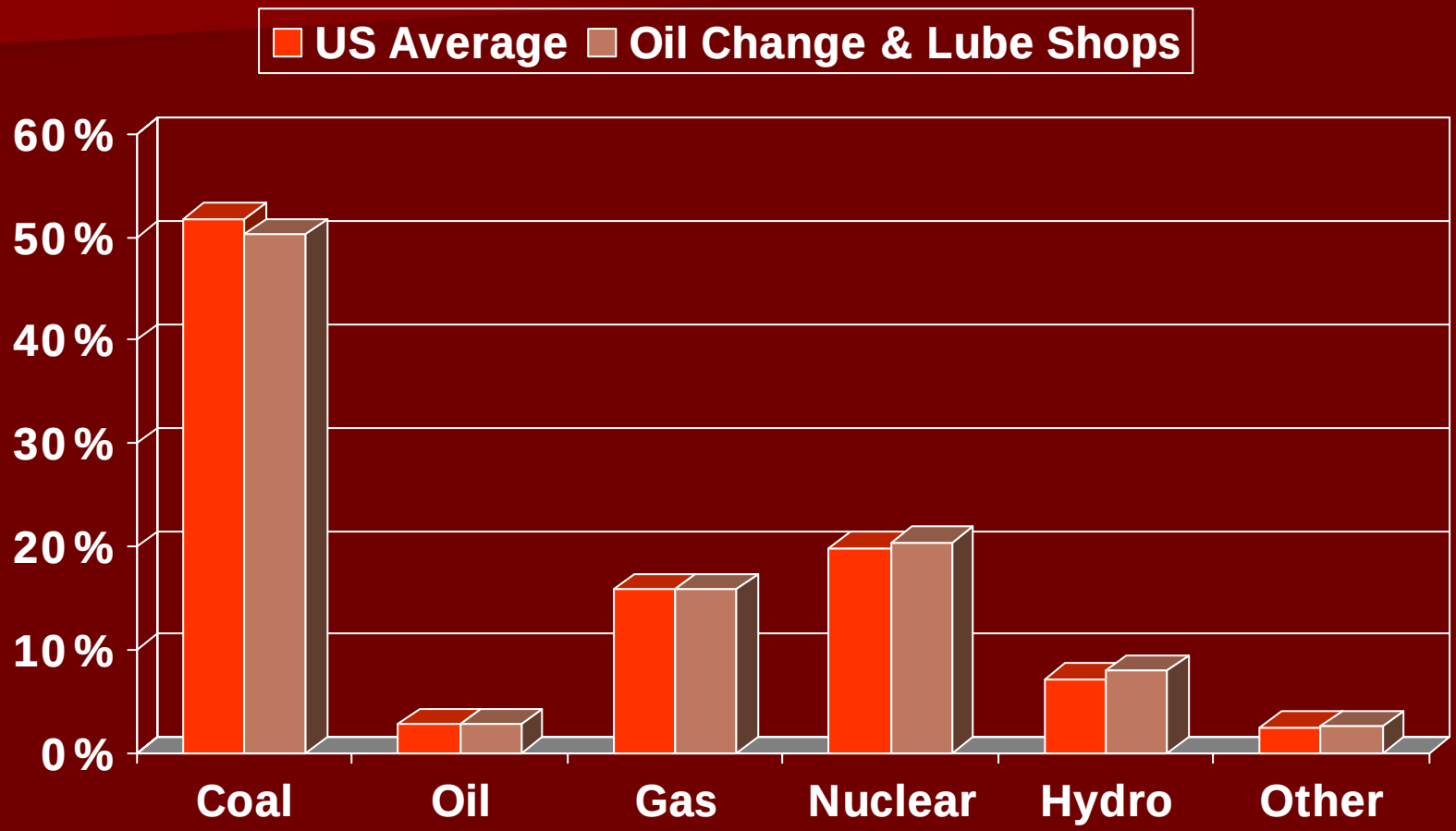
Aircraft Manufacturing



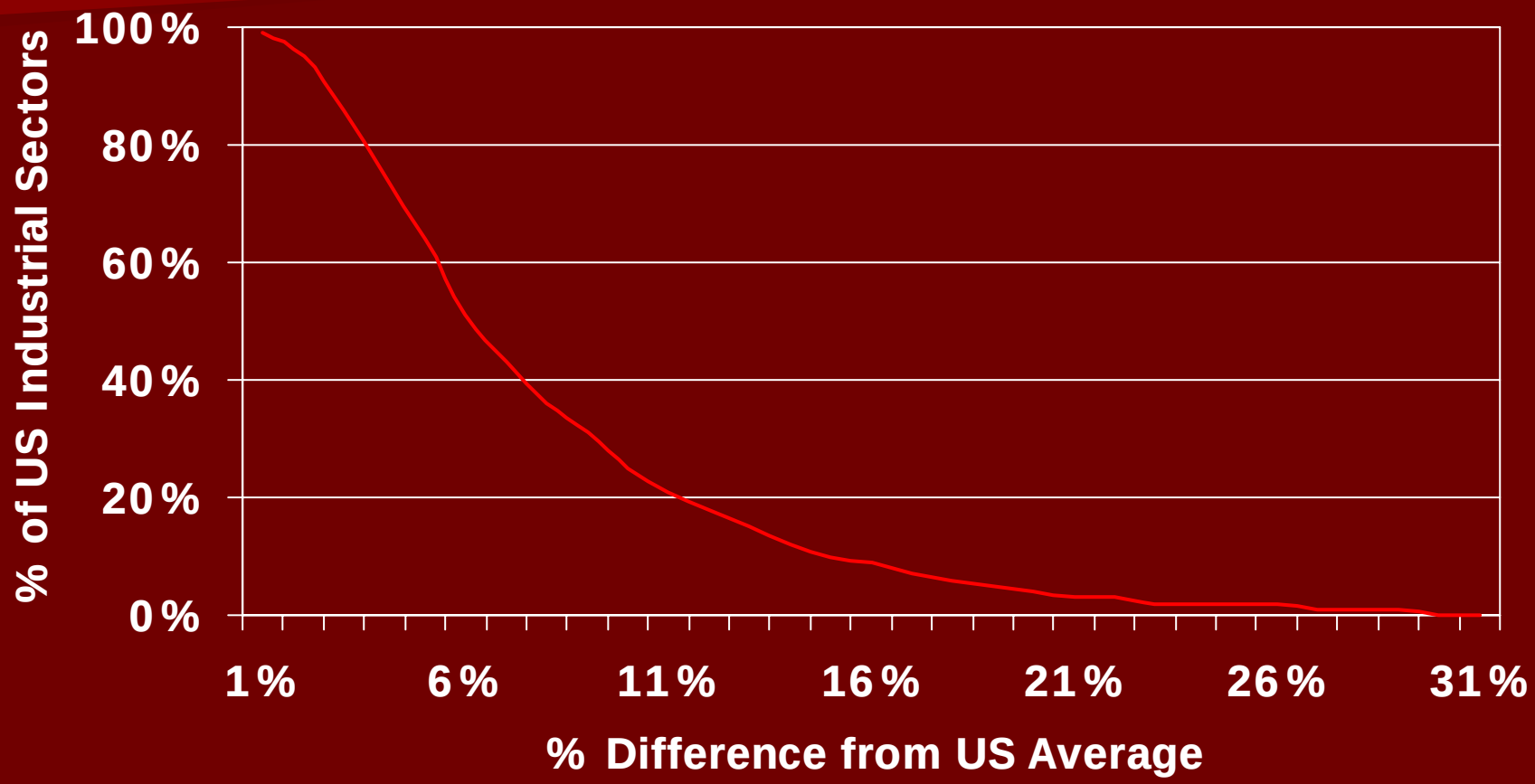
Dirty Laundry? And How!



United States: Well Oiled



Results Trend Towards Average



Contributions

- Disaggregating adds accuracy to a critical sector in terms of environmental impact
- Industrial sector generation mixes answer some interesting questions
  - Which sectors are vulnerable to shifts in fuel price or technology change?
  - What is the potential impact of carbon taxes on the US economy?
- Import-export estimate an intuitive substitute for complete transmission grid analysis
- Most industrial sectors have a mix close to the US average mix
  - Some interesting sectors have significant differences